8.0 Permit Requirements

D. Discharge Characterization

Baltimore County and 10 other municipalities in Maryland have been conducting discharge characterization monitoring since the early 1990's. From this expansive monitoring, a statewide database has been developed that includes hundreds of storms across numerous land uses. Summaries of this dataset and other research performed nationally effectively characterize stormwater runoff in Maryland for NPDES municipal stormwater purposes. These data shall be used by Baltimore County for guidance to improve stormwater management programs and develop watershed restoration projects. Monitoring required under this permit is now designed to assess the effectiveness of stormwater management programs and watershed restoration projects developed by the County. Details about this monitoring can be found in PART III. H.

H. Assessment of Controls

Assessment of controls is critical for determining the effectiveness of the NPDES stormwater management program and progress toward improving water quality. Therefore, Baltimore County shall use chemical, biological, and physical monitoring to document work toward meeting the watershed restoration goals identified above. Additionally, the County shall continue physical stream monitoring in the Windlass Run to assess the implementation of the *2000 Maryland Stormwater Design Manual* or other innovative stormwater management technologies approved by MDE. Specific monitoring requirement are described below.

1. Watershed Restoration Assessment

   The County shall monitor the Scotts Level Branch, or, select and submit for MDE's approval a new watershed restoration project for monitoring. Ample time shall be provided so that pre-restoration monitoring, or characterization monitoring can take place. Priority will be given to new practices where little monitoring data exist or where the cumulative effects of watershed restoration activities can be assessed. An outfall and associated in-stream station, or other locations based on an approved study design shall be monitored. The minimum criteria for chemical, biological, physical monitoring are as follows:

   a. Chemical Monitoring

      i. Twelve (12) storm events shall be monitored per year at each monitoring location with at least three occurring per quarter. Quarters shall be based on the calendar year. If extended dry weather periods occur, baseflow samples shall be taken at least once per month at the monitoring stations if flow is observed;

      ii. Discrete samples of stormwater flow shall be collected at the monitoring stations using automated or manual sampling methods. Measurements of pH and water temperature shall be taken;

iii. At least three (3) samples determined to be representative of each storm event shall be submitted to a laboratory for analysis according to methods listed under 40 CFR Part 136 and event mean concentrations (EMC) shall be calculated for:

Biochemcial Oxygen demand (BOD_5)	Total Lead
Total Kjeldahl Nitrogen (TKN)	Total Copper
Nitrate plus Nitrite	Total Zinc
Total Suspended Solids	Total Phosphorus
Total Petroleum Hydrocarbons (TPH)	Oil and Grease*
Fecal Coliform or E. coli	(*Optional).

iv. Continuous flow measurements shall be recorded at the in-stream monitoring station or other practical locations based on an approved study design. Data collected shall be used to estimate annual and seasonal pollutant loads and for the calibration of the watershed assessment models.

b. Biological Monitoring

i. Benthic macroinvertebrate samples shall be gathered each Spring between the outfall and in-stream stations or other practical locations based on an approved study design; and

ii. The County shall use the U.S. Environmental Protection Agenciy's (EPA) Rapid Bioassessment Protocols (RBP), Maryland Biological Stream Survey (MBSS), or other similar method approved by MDE.

c. Physical Monitoring

i. A geomorphologic stream assessment shall be conducted between the outfall and in-stream monitoring locations or in a reasonable area based on an approved study design. This assessment shall be include an annual comparison of permanently monumented stream channel cross-sections and the stream profile;

ii. A stream habitat assessment shall be conducted using techniques defined by the EPA's RBP, MBSS, or other similar method approved by MDE; and

iii. A hydrologic and/or hydraulic model shall be used (e.g., TR-20, HEC-2, HSPF, SWMM, etc.) to analyze the effects of rainfall discharge rates; stage; and if necessary, continuous flow on channel geometry.

d. Annual Data Submittal: The County shall describe in detail its monitoring activities for the previous year and include the following:

i. EMCs submitted on MDE's long-term monitoring database as specified in PART IV below;

Chemical, biological, and physical monitoring results and a combined analysis for the Scotts Level Branch or other approved monitoring

ii. locations; and

iii. Any requests and accompanying justifications for proposed modification to the monitoring program.

2. Stormwater Management Assessment

The County shall continue monitoring the Windlass Run for determining the effectiveness of the *2000 Maryland Stormwater Design Manual* for stream channel protection. Physical stream monitoring protocols shall include:

a. An annual stream profile and survey of permanently monumented cross-sections in the Windlass Run to evaluate channel stability in conjunction with the implementation of the *2000 Maryland Stormwater Design Manual*.

b. A comparison of the annual stream profile and survey of the permanently monumented cross-sections with baseline conditions for assessing areas of aggradation and degradation; and

c. A hydrologic and/or hydraulic model shall be used (e.g., TR-20, HEC-2, HEC-RAS, HSPF, SWMM, etc.) to analyze the effects of rainfall discharge rates; stage; and, if necessary, continuous flow on channel geometry.

8.1 Introduction

The third term of the Baltimore County – NPDES MS4 Permit that became effective June 15, 2005 resulted in a change in the long-term monitoring location. The long-term monitoring site was moved from Spring Branch in the Loch Raven watershed to Scotts Level Branch in Gwynns Falls watershed. This report will present the research design and monitoring data for Scotts Level Branch (8.2, 8.3), and the data for Windlass Run (8.4).

8.2 Scotts Level Branch Long-Term Monitoring

The Baltimore County NPDES Municipal Stormwater Discharge Permit requires monitoring of restoration effectiveness. For the first two rounds of the 5-year permit, the Spring Branch subwatershed had been monitored to determine the effectiveness of the stream restoration in promoting stream stability, reduction in pollutant loads, and improvement in the benthic macroinvertebrate community. Using the experience gained in monitoring Spring Branch, a more effective monitoring program has been designed for the Scotts Level Branch subwatershed, as detailed below.

Scotts Level Branch is located in the Gwynns Falls watershed in the Patapsco/Back River Basin. The 303(d) lists these waters as being impaired by nutrients, suspended sediments, and fecal coliform bacteria. In addition, Scotts Level Branch is listed as impaired for biology. The TMDLs for nutrients and bacteria have been completed. The TMDL for nutrients has identified a reduction of 15% nitrogen and phosphorus loads from urban non-point sources as needed to meet water quality standards in Baltimore Harbor. The TMDL for bacteria has identified a ~98% reduction for human and domestic pet sources.

While the Spring Branch study monitored the effectiveness of one large restoration project, the Scotts Level Branch monitoring is designed on the basis that a number of restoration projects will be implemented within the subwatershed over a period of time. The ability to detect effects

of individual restoration projects will be dependent on the size of the restoration project in relation to the total subwatershed size. Therefore each restoration project will be monitored for project effectiveness, dependent on staff availability. The cumulative effects of restoration will be measured at the long-term in-stream monitoring site.

In order to assess restoration progress in the Scotts Level Branch subwatershed, a paired watershed, before-after design concept will be used. Two additional subwatersheds within Gwynns Falls, Powder Mill Run and Upper Gwynns Falls (above Gwynnbrook Road) have been selected as the "paired" subwatersheds (Figure 8-1).

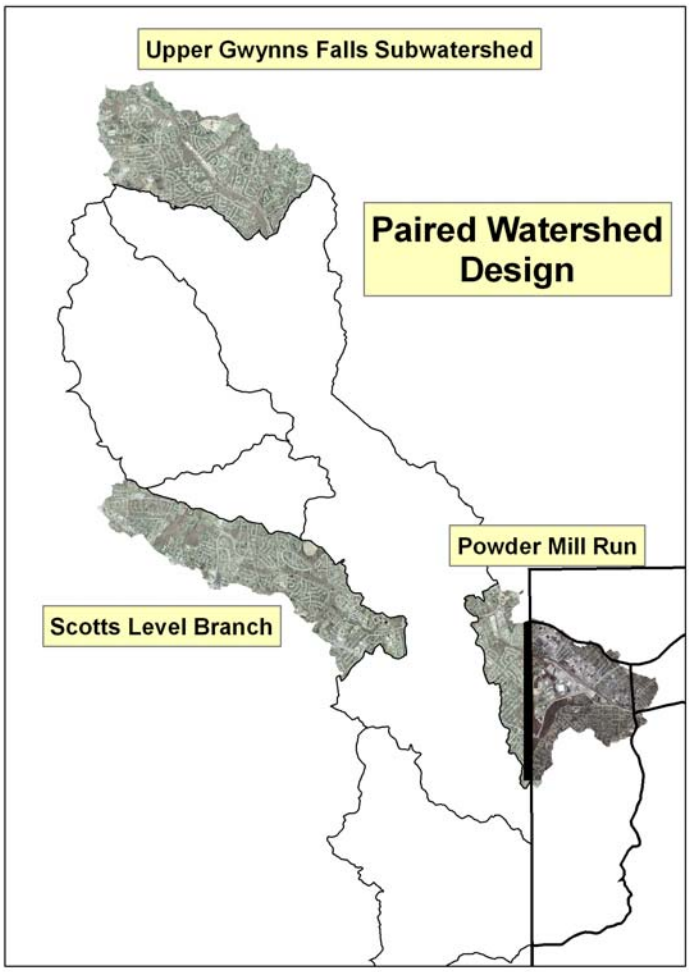


Figure 8-1: Subwatersheds to be used in the Paired Watershed Monitoring Design.

Table 8-1 presents a comparison between the three subwatersheds in relation to overall size, land use composition, percent impervious cover, and stream length. The third subwatershed (Upper Gwynns Falls) was added due to the fact that Baltimore City will be doing stream restoration work in the Powder Mill Run subwatershed. Restoration work will also be conducted in the

Upper Gwynns Falls subwatershed in the future, with restoration work in Scotts Level Branch beginning in a few years.

Table 8-1: Scotts Level Branch, Powder Mill Run, and Upper Gwynns Falls Information

Parameter	Scotts Level Branch	Powder Mill Run	Upper Gwynns Falls
Area (acres)	2,186	2,436	2,637
Land Use			
% Residential	91.1	63.4	74.9
% Commercial/Ind	6.0	32.5	6.3
% Forest	2.9	4.1	11.6
Impervious Cover (%)	23.7	33.8	21.4
Stream Miles	8.0	5.9	11.1

The monitoring will consist of flow monitoring, chemical monitoring, geomorphological monitoring, and biological monitoring as described below.

8.2.1 Monitoring Design

8.2.1.1 Flow Monitoring

Each of the three subwatersheds has had a gage installed and operated by the US Geological Survey (Table 8-2) with funding provided in total for the Powder Mill Run and Scotts Level Branch gages and in part for the Upper Gwynns Falls gage (Delight). USGS is providing the rating curves for the gages and annual data. A 36" outfall near the headwater of Scotts Level Branch is being monitored for discharge and chemistry. A weir was installed to permit continuous flow monitoring with a water level sensor installed and operated by Baltimore County. This outfall has a drainage area of 15.0 acres with ~35% impervious cover. The land use is ~88% medium residential and therefore representative of the major land use in each of the subwatersheds.

Table 8-2: USGS Gage Information

Gage Number	Location	Measurements			Real Time	Period of Record
		Stage	Discharge	Precipitation		
01589197	Upper Gwynns Falls	X	X	X	Yes	October, 1998 - Current
01589305	Powder Mill Run	X	X		Yes	November, 2005 – Current
01589290	Scotts Level Branch	X	X		Yes	November, 2005 – Current

The flow monitoring will be used in conjunction with the chemical monitoring (described below) to determine pollutant loads and in relation to the geomorphological monitoring. Over time the flow data will be assessed for any changes in relation to restoration work that is conducted in the subwatersheds.

8.2.1.2 Chemical Monitoring

The chemical monitoring will include both storm event and baseflow monitoring components. The standard list of chemicals detailed in the permit requirements will be analyzed. Figure 8-2 displays the location of the chemical monitoring sites in Scotts Level Branch by type.

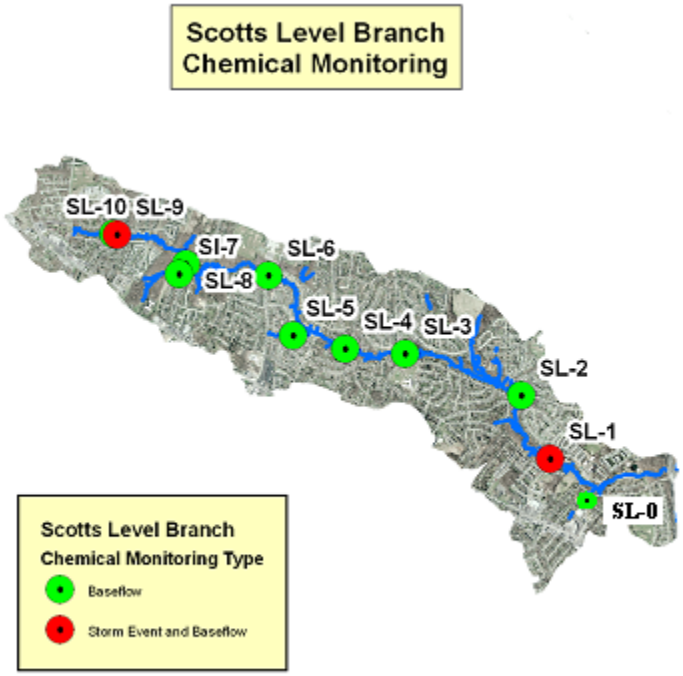


Figure 8-2: Scotts Level Branch Chemical Monitoring Locations

Storm Event Monitoring

Storm event monitoring will occur at each of the three USGS gages and at the outfall. The two Scotts Level Branch storm event monitoring sites (SL-1 in-stream, and SL-9 outfall) will be monitored for 12 storms each calendar year seeking to acquire samples for the entire hydrograph. At the other USGS gage at the Upper Gwynns Falls storm event grab samples will be collected to represent a range of stage discharges. The data for the Powder Mill site will come from Baltimore City. The data from all four sites will be analyzed using regression analysis to determine the relationship between discharge and pollutant concentration. These relationships will then be used in conjunction with the flow data collected from the USGS operated gages and the water level sensor operated by EPS. The results and subsequent analysis following restoration will be used to determine annual loads and any load reductions due to restoration activities.

The pollutant load data collected from the Scotts Level Branch outfall will be used to estimate the wash load (the load derived from the land surface). While the pollutant load estimate derived from the Scotts Level Branch in-stream site will estimate the watershed load, which includes both the wash load and the load derived from stream bank erosion. The geomorphological analysis (see below) will attempt to determine the stream channel erosion component via changes in the channel cross-section and analysis of the pollutant concentration of the stream bank and bed. Thus the wash load (derived from the outfall data) plus the stream erosion load (derived from the geomorphological data) should equal the watershed load (derived from the in-stream monitoring data). These data should provide an estimate of the relative proportions of

pollutants derived from the land surface and the stream corridor. This will have important implications for restoration efforts in urban settings. If, as the literature suggests, a large component of the sediment and total phosphorus load is derived from the stream channel, then in order to meet sediment and phosphorus load reduction requirements for TMDLs and the Chesapeake Bay Program additional effort will need to be focused on stream restoration.

Baseflow Monitoring

Scotts Level Branch baseflow monitoring will occur at the outfall (SL-9), three tributary locations, and six mainstem locations for a total of 11 baseflow monitoring sites (Figure 8-2). The site below SL-01 was added last year in order to collect some information on what may be coming from the tributary below the gage. Within Powder Mill Run baseflow monitoring will take place at the USGS gage and two up-stream sites that are representative of each major branch (one in the County and one in the City). Baseflow monitoring in Upper Gwynns Falls will occur only at the USGS gage site. The baseflow sites in Scotts Level Branch, Powder Mill Run, and Upper Gwynns Falls will be monitored quarterly during baseflow conditions (preceded by a minimum of 72 hours dry weather).

Analysis of baseflow pollutants is especially important in relation to nitrogen. Research work conducted by the County, indicates that ~50% of the nitrogen load occurs during dry weather conditions. The baseflow sampling will be used in conjunction with the storm event sampling to partition the annual discharge and pollutant load between baseflow (dry weather) conditions and storm event conditions.

8.2.1.3 Geomorphological Monitoring

The geomorphological monitoring is intended to provide an estimate of stream erosion and deposition rates, and an estimate of the pollutant load derived from stream channel erosion. In addition, it is intended over time to provide an estimate of the effects of restoration on stream stability on both a project basis and over the entire subwatershed.

In order to assure unbiased selection of cross-section locations, Scotts Level Branch and Powder Mill Run were divided into 30 equal length stream segments, 20 in Scotts Level Branch (Figure 8-3) and 10 in Powder Mill Run (Figures 8-4). Within each segment a point was randomly selected, using a GIS subroutine, for location of permanent cross sections. These cross sections are monitored annually with the results overlaid to provide an assessment of the amount of channel change. Two longitudinal profile reaches were selected in Scotts Level Branch for annual assessment.

Stream bank and bed core samples are collected in the vicinity of the permanent cross sections for laboratory analysis of bulk density, particle size distribution, total nitrogen, and total phosphorus. These are one-time sample collections, with 10% of the sites, randomly selected, for a second round of sample collection to provide an analysis of annual variability. Based on the annul and long term change, and the results of the core samples, the estimated annual sediment, total nitrogen, and total phosphorus loads will be calculated for comparison with the chemical monitoring results derived from the in-stream monitoring site.

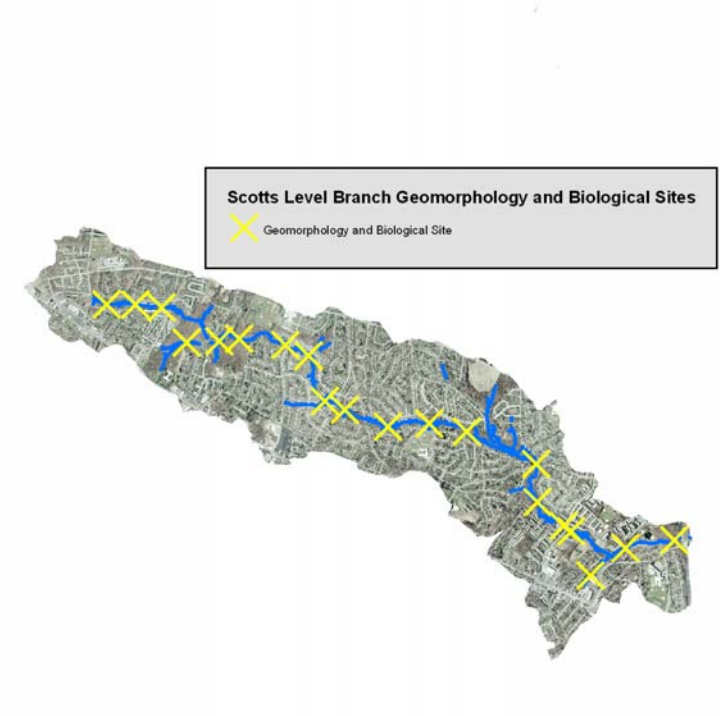


Figure 8-3: Scotts Level Branch Geomorphological and Biological Monitoring Site Locations

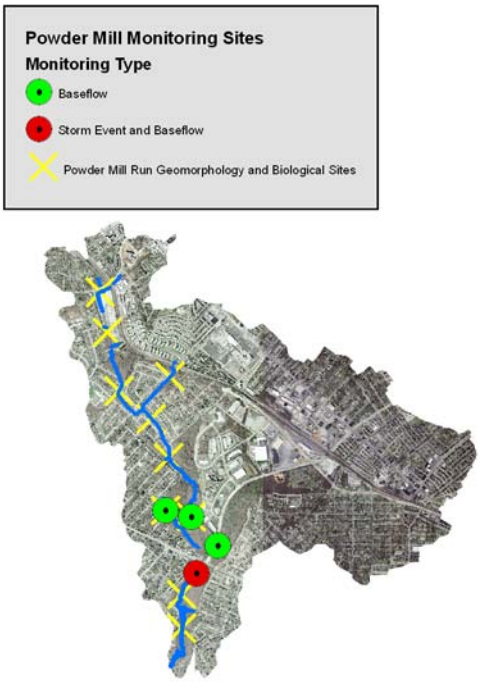


Figure 8-4: Powder Mill Run Chemical, Geomorphological and Biological Monitoring Sites

8.2.1.4 Biological Monitoring

Benthic macroinvertebrate and fish sampling is conducted annually at five fixed stations on Scotts Level Branch and three fixed stations on Powder Mill Run, during the appropriate index periods (March-April for macroinvertebrates, June-September for fish). Maryland Biological Stream Survey (MBSS) methods are followed. Macroinvertebrate identification is to the Genus taxonomic level or the lowest practical identification level. At the time of sample collection, the appropriate MBSS stream habitat assessment is conducted.

The biological monitoring data are integrated with the cross sectional and habitat data to produce an overall assessment of conditions in the subwatersheds. In addition, the results will be compared between the two subwatersheds and to reference sites within Baltimore County. Inter-annual comparisons and changes in the biological community will be related to restoration progress within Scotts Level Branch.

8.3 Scotts Level Branch Long-Term Site Monitoring Results

8.3.1 Precipitation and Flow Monitoring

The U.S. Geological Survey under an agreement with Baltimore County installed a continuous gage on Scotts Level Branch where it crosses Rolling Road on September 29, 2005. This site is designated as SL-01. They also installed a continuous gage on Powder Mill Run below Liberty Road. In the fall of 2007, a weir with a continuous gage was installed at the outfall in Scotts Level Branch to provide a continuous discharge record. The data for Scotts Level Branch and the outfall are analyzed in this report.

There was a problem using discharge data for the days when the SL-09 outfall was partially frozen. Possibly ice in the pipe was causing water to back into the pipe; depths for these days were abnormally high. A correlation was run with the SL-01 gage and found to be significant. A regression analysis was used to extrapolate what the real discharge was for those days, based on what discharge was at the SL-01 gage.

Precipitation Data: Hourly and daily precipitation data used for SL-01 were acquired from the Department of Public Works rain gage located on Carlson Lane. Precipitation data for SL-09 were acquired from the Department of Public Works rain gage located on Lyon's Mill Road. These data were recorded in conjunction with the Scotts Level Branch discharge data discussed below. Calendar year 2010 had one hundred three days of recorded measurable precipitation at SL-01. SL-09 had one hundred four days of precipitation. The daily data were analyzed for precipitation amount (Table 8-3). As can be seen from Table 8-3a, 33% of the days recorded less than a 0.1 inch of precipitation. Table 8-3b shows 32% of the days recorded had less than 0.1 inch of precipitation. Precipitation over one inch occurred on only 7% of the days, but accounted for about 39% of the total amount of the precipitation in 2009 at SL-01. SL-09 had precipitation over one inch on only 8% of the days, but this accounted for about 37% of the total precipitation. The maximum daily rainfall at SL-01 was 4.19 inches, recorded on September 30, 2010. The maximum for SL-09 was 3.36 inches, recorded on the same date. A total of 38.13 inches of precipitation, less than the long-term average (~42 inches), was recorded at the Department of Public Works Carlson Lane rain gauge for 2010. The Lyon's Mill rain gage recorded 37.02 inches.

Table 8- 3a: SL-01 Precipitation Data Analysis for Calendar 2010

Precipitation Category	# of Days	% Days	Total Amount	% of accumulation
<.1	34	33%	1.35	3.54%
.1-<.5	45	44%	9.95	26.1%
.5-<1.0	17	16%	12.07	31.65%
1.0-<1.5	2	2%	2.07	5.43%
1.5-<2.0	1	1%	1.65	4.33%
2.0-<2.5	3	3%	6.85	17.96%
2.5-<3.0	0	0%	0	0.00%
3.0-3.5	1	1%	4.19	10.99%
Total	**103**		**38.13**	

Table 8- 3b: SL-09 Precipitation Data Analysis for Calendar 2010

Precipitation Category	# of Days	% Days	Total Amount	% of accumulation
<.1	33	32%	1.14	3.08%
.1-<.5	47	45%	10.3	27.82%
.5-<1.0	16	15%	11.74	31.71%
1.0-<1.5	4	4%	4.4	11.89%
1.5-<2.0	2	2%	3.86	10.42%
2.0-<2.5	1	1%	2.22	6.00%
2.5-<3.0	0	0%	0	0.00%
3.0-3.5	1	1%	3.36	9.08%
Total	**104**		**37.02**	

Often storms span more than one day. The hourly precipitation data were used to delimit individual storms. All precipitation was counted as a storm, and the end of the storm event defined as about thirty-six hours with no rainfall recorded. A total of 60 and 59 distinct storms were identified for SL-01 and SL-09 during 2010. These storms were analyzed for amount of precipitation, intensity (inches/hour), and duration. The results of this analysis are presented in Table 8-4.

Table 8-4a: 2010 Precipitation Amount, Intensity, and Duration by Category for SL-01

Precipitation Category (Inches)	Accumulation Amount				Intensity (inches/hour)			Duration (hours)		
	# Storms	% Storms	Total Acc.	% Acc.	Intensity Category	# Storm	% storms	Duration Category	# storms	% storms
< .1	11	18.3	0.46	1.2	< .1	50	83.3	<1	11	18.3
.1 - <.25	14	23.3	2.07	5.4	.1 - <.25	5	8.3	1 – <3	6	10.0
.25 - <.50	11	18.3	3.7	9.7	.25 - <.50	4	6.7	3 – <6	7	11.7
.50 - <.75	5	8.3	2.99	7.8	.50 - <.75	0	0.0	6 – <9	7	11.7
.75 – <1.00	9	15.0	7.72	20.2	.75 – <1.00	0	0.0	9 – <12	1	1.7
1.00 – <1.50	5	8.3	5.42	14.2	1.00 – <1.50	1	1.7	12 – <15	2	3.3
1.50 – <2.00	0	0.0	0.00	0.0	1.50 – <2.00	0	0.0	15 – <18	2	3.3
2.00 – <3.00	2	3.3	5.21	13.7	2.00 – <3.00	0	0.0	18 – <21	2	3.3
3.00 – 4.00	2	3.3	6.27	16.4	3.00 – 4.00	0	0.0	21 – 24	1	1.7
>4.00	1	1.7	4.29	11.3	>4.00	0	0.0	>24	21	35.0
Total	**60**		**38.13**			**60**			**60**	

Table 8-4b: 2010 Precipitation Amount, Intensity, and Duration by Category for SL-09

Precipitation Category (Inches)	Accumulation Amount				Intensity (inches/hour)			Duration (hours)		
	# Storms	% Storms	Total Acc.	% Acc.	Intensity Category	# Storm	% storms	Duration Category	# storms	% storms
< .1	15	22.1	0.83	1.6	< .1	49	83.1	<1	10	16.9
.1 - <.25	16	23.5	2.58	5.0	.1 - <.25	3	5.1	1 – <3	5	8.5
.25 - <.50	4	5.9	1.65	3.2	.25 - <.50	7	11.9	3 – <6	8	13.6
.50 - <.75	11	16.2	5.58	10.8	.50 - <.75	0	0.0	6 – <9	5	8.5
.75 – <1.00	2	2.9	3.05	5.9	.75 – <1.00	0	0.0	9 – <12	4	6.8
1.00 – <1.50	8	11.8	9.13	17.6	1.00 – <1.50	0	0.0	12 – <15	1	1.7
1.50 – <2.00	4	5.9	6.64	12.8	1.50 – <2.00	0	0.0	15 – <18	2	3.4
2.00 – <3.00	6	8.8	14.81	28.6	2.00 – <3.00	0	0.0	18 – <21	3	5.1
3.00 – <4.00	2	2.9	7.50	14.5	3.00 – <4.00	0	0.0	21 – <24	0	0.0
>4.00	0	0.0	0.00	0.0	>4.00	0	0.0	>24	21	35.6
Total	**59**		**37.02**			**59**			**59**	

At SL-01 and SL-09, 42% and 46% of the storms were less than 0.25 inches in total amount of precipitation, but these storms accounted for only 6.6% of the total amount of rainfall at both sites. Only 16.6% and 29.4% of the storms at SL-01 and SL-09 were over one inch in total amount of rainfall and but these storms accounted for over half (55.6% and 73.5%) of the total amount of precipitation in 2010. The largest storm for 2010 at SL-01 recorded 4.29 inches of precipitation over about a three day period. The largest storm at SL-09 recorded 3.47 inches of precipitation over about a two day period. The highest intensity recorded at SL-01 and SL-09 was 1.36 inches per hour and 0.44 inches per hour (two storms). The majority of storms at SL-01 and SL-09 (83.3% and 83.1%) highest recorded hourly intensity were less than one-tenth inch per hour. About one third of the storms at SL-01 and SL-09 (35.0% and 35.6%) were greater than 24 hours in duration.

Flow Data: The Scotts Level Branch gage data for SL-01 (Rolling Road instream site) includes 15-minute discharge readings from the period of October 1, 2005 to December 31, 2010. The gage data for SL-09 (outfall) includes 15-minute discharge readings from January 1, 2010 to December 31, 2010. The entire record was analyzed for storm events. The data were visually scanned to determine the inception of each storm event. The termination of the event for SL-01 was based on comparison of discharge to the daily baseflow developed from the USGS Part program, a computerized method of baseflow record estimation. Data for SL-09 were visually assessed and precipitation and increases in discharge were used to determine storm flow. A total of 328 storm events for the period of record at SL-01 were identified, of which, 69 occurred in the calendar year 2010. Seventy-two storms occurred at SL-09 during 2010. Figure 8-5 displays the daily discharge and precipitation for calendar year 2010 at SL-01 and SL-09.

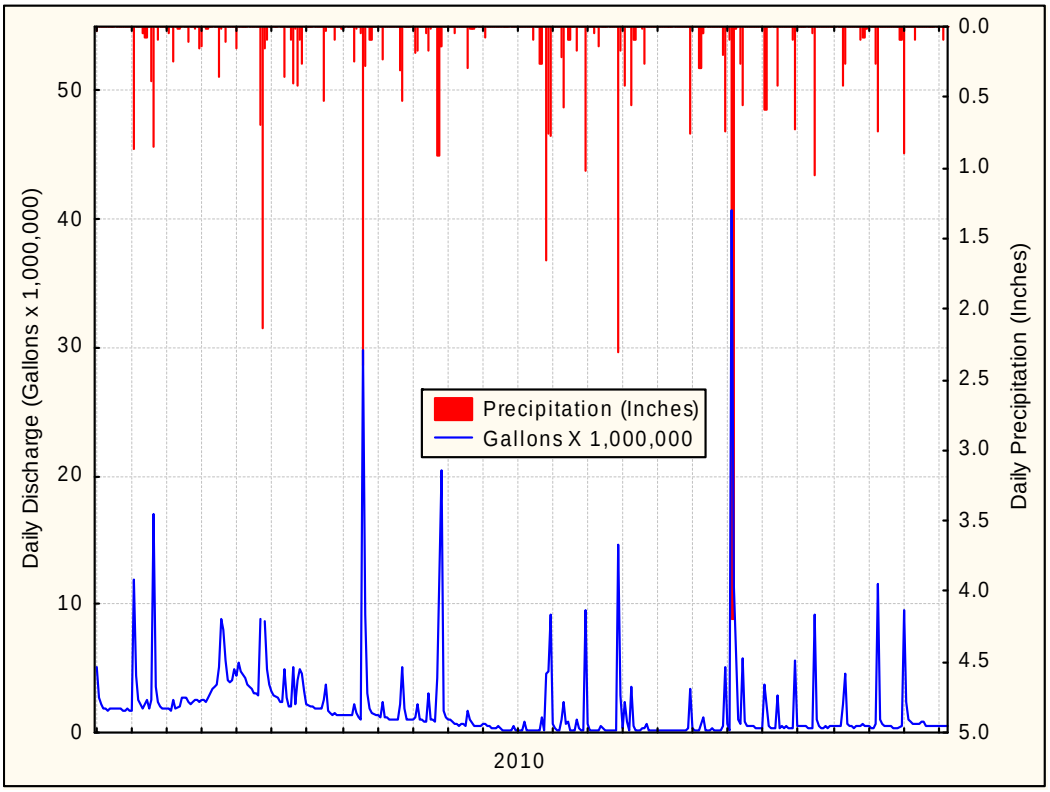


Figure 8-5a: Calendar year 2010 Daily Precipitation and Discharge at SL-01

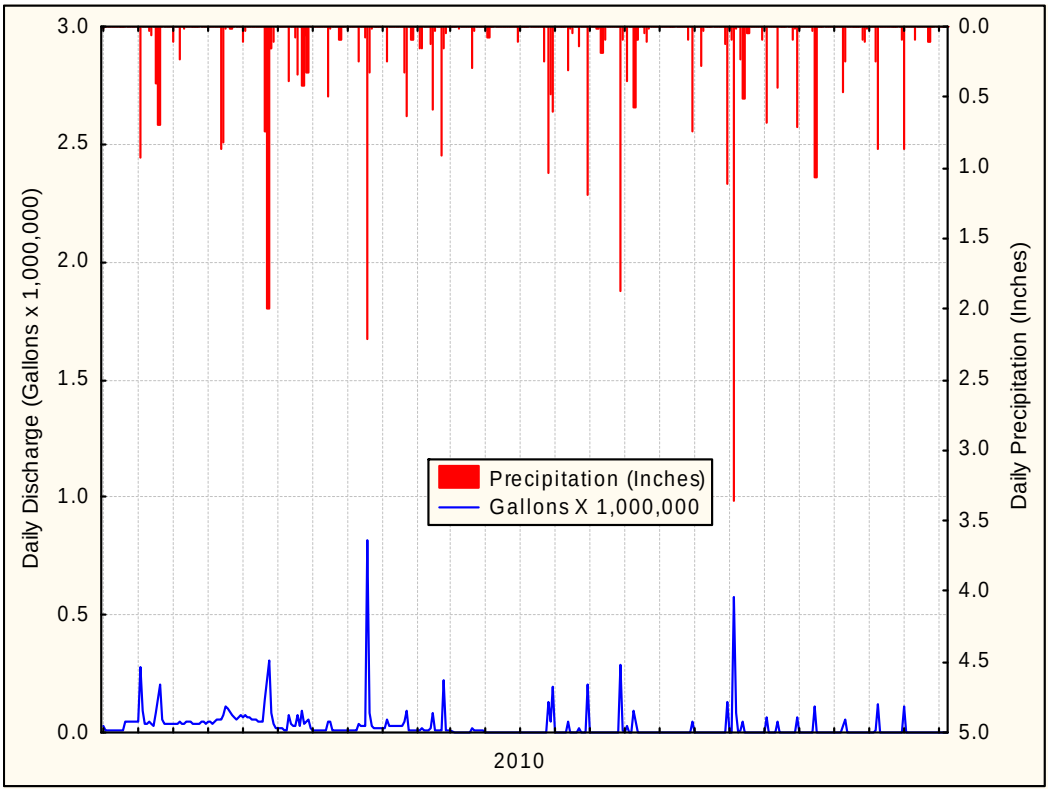


Figure 8-5b: Calendar year 2010 Daily Precipitation and Discharge at SL-09

The runoff coefficient was calculated for each storm. The average runoff coefficient at SL-01 was 0.37, with a maximum of 5.17 and a minimum of 0.027. The average runoff coefficient at SL-09 was 0.012, with a maximum of 0.46 and a minimum of 2.3×10^{-6}.

The storm data sets were further analyzed to determine the proportion of runoff to total precipitation, and the relative proportions of baseflow and storm event runoff. These data were analyzed by season for calendar year 2010 at SL-01 and SL-09. The results are presented in Table 8-5.

Table 8-5a: Seasonal Precipitation and Runoff Characteristics SL-01

Parameter	Fall	Winter	Spring	Summer	Total
Precipitation Amount	11.95	6.90	8.51	10.77	38.13
Precipitation %	31.3 %	18.1 %	22.3%	28.2 %	---
% of precipitation volume accounted for by Runoff	21.7%	83.5%	41.4%	12.9%	34.8%
% of precipitation volume accounted for by Evapotranspiration	78.3 %	16.5%	58.6%	87.1%	65.2 %
% of stream flow accounted for by Storm flow	83.1%	67.9%	66.6%	85.4%	72.3%
% of stream flow accounted for by Baseflow	16.9%	32.1%	33.4%	14.6%	27.7%

Table 8-5b: Seasonal Precipitation and Runoff Characteristics SL-09

Parameter	Fall	Winter	Spring	Summer	Total
Precipitation Amount	11.7	7.46	8.97	8.82	37.02
Precipitation %	31.8 %	20.2%	24.2%	23.5 %	---
% of precipitation volume accounted for by Runoff	30.6%	70.8%	77.6%	34.8%	66.6%
% of precipitation volume accounted for by Evapotranspiration	69.4%	29.2%	22.4%	65.2%	33.4 %
% of stream flow accounted for by Storm flow	87.9%	59.2%	71.2%	90.7%	71.3%
% of stream flow accounted for by Baseflow %	12.1%	40.8%	28.8%	9.3%	28.7%

Table 8.5 shows the fall exhibited highest precipitation for both sites. About thirty-five percent of the precipitation was accounted for by stream flow at SL-01 while the balance was assumed to be evapotranspiration. At SL-09, about 67% of the outfall flow was accounted for by precipitation. The evapotranspiration is the result of the evaporation of water, which is temperature dependant and the transpiration of water due to plants. Thus the expectation is that winter should exhibit the lowest evapotranspiration rates and summer the highest rate. The results for SL-01 bear this out with 16.5% and 87.1% evapotranspiration rates for winter and summer, respectively. SL-09 has lower rates of evapotranspiration in the winter and spring. As is characteristic of urban watersheds, SL-01 exhibits a shift in runoff from baseflow dominated to storm flow dominated. For 2010, 72.3% of the flow was determined to be storm flow using the criteria described above, while only 27.3% was characterized as baseflow. SL-09 shows a similar pattern, with 71.3% from stormflow and 28.7% from baseflow. The SL-09 has groundwater input and has flow all the time, except in drought and freezing conditions.

8.3.2 Chemical Monitoring

The data analysis for chemical monitoring includes three components, storm event monitoring (8.3.2.1), baseflow monitoring (8.3.2.2), and the calculation of pollutant loads (8.3.2.3)

8.3.2.1 Storm Event Monitoring Results

The chemical results from the storm event monitoring at the Scotts Level Branch in-stream monitoring and outfall sites were analyzed in conjunction with the discharge data. Both the chemical and the discharge data were $\log_{10}$ transformed prior to regression analysis. The data for the regression equations was censored by removing any chemical data that was below the detection limit for any constituent. Regression equations were determined for Total Suspended Solids, TKN, Nitrate/Nitrite, Total Nitrogen, and Total Phosphorus, Total Copper, Total Lead, Total Zinc, Chloride and Sodium. The results are displayed in Table 8-6 and graphically in Appendix 1.

Table 8-6a: SL-01 Regression Equations Relationship Between Discharge (CFS) and Pollutant Concentrations

Parameter	Regression Equation
Total Suspended Solids	0.9495+0.4693*(log cfs)
Total Kjeldahl Nitrogen	-0.3109+0.1483*(log cfs)
Nitrate/Nitrite	-0.2144-0.1187*(log cfs)
Total Nitrogen	0.0369+0.0596*(log cfs)
Total Phosphorus	-1.2969+0.3053*(log cfs)
Total Copper	-2.3431+0.1951*(log cfs)
Total Lead	-3.1188+0.4122*(log cfs)
Total Zinc	-2.1377+0.3395*(log cfs)
Chloride	1.7237-0.1643*(log cfs)
Sodium	1.603-0.0962*(log cfs)

Table 8-6b: SL-09 Regression Equations Relationship Between Discharge (CFS) and Pollutant Concentrations

Parameter	Regression Equation
Total Suspended Solids	1.3579+0.2055*(log cfs)
Total Kjeldahl Nitrogen	0.0031-0.0217*(log cfs)
Nitrate/Nitrite	-0.453-0.0697*(log cfs)
Total Nitrogen	0.1637-0.0363*(log cfs)
Total Phosphorus	-0.8126+0.0072*(log cfs)
Total Copper	-1.9628+0.0042*(log cfs)
Total Lead	-2.5362+0.0134*(log cfs)
Total Zinc	-1.5263+0.0332*(log cfs)
Chloride	1.0565-0.0417*(log cfs)
Sodium	1.195-0.1481*(log cfs)

For SL-01 Total Suspended Solids, Total Phosphorus, Total Copper, Total Lead and Total Zinc exhibited strong positive relationships with discharge, while no parameters displayed a strong negative relationship with discharge. The TKN and TN (TKN+Nitrate/Nitrite Nitrogen) relationship with discharge was relatively weak and positive. Nitrate/Nitrite, Chloride, and Sodium displayed a weak and negative relationship.

For SL-09 The Total Suspended Solids exhibited a strong positive relationship with discharge, while no parameters displayed a strong negative relationship. The Total Phosphorus, Total Copper, Total Lead, Total Zinc and Sodium relationship with discharge was relatively weak and

positive. Nitrate/Nitrite, TKN, TN (TKN+Nitrate/Nitrite Nitrogen), and Chloride displayed a weak and negative relationship.

The regression equations were used to calculate the chemical concentrations for each 15-minute interval for recorded discharge. The log chemical concentrations were then back transformed. This permitted the calculation of the flow weighted Event Mean Concentrations for the SL-01 SL-09 2010 storms. Results are shown graphically in Appendix 2.

8.3.2.2 Baseflow Monitoring Results

Scotts Level Branch baseflow monitoring occurred at the outfall (SL-9), three tributary locations, and six mainstem locations for a total of 11 baseflow monitoring sites (Figure 8-2). Within Powder Mill Run baseflow monitoring will take place at the USGS gage and two up-stream sites that are representative of each major branch (one in the County and one in the City). Baseflow monitoring in Upper Gwynns Falls will occur only at the USGS gage site. The baseflow sites in Scotts Level Branch, Powder Mill Run, and Upper Gwynns Falls will be monitored quarterly during baseflow conditions (preceded by a minimum of 72 hours dry weather).

Analysis of baseflow pollutants is especially important in relation to nitrogen. Research conducted by the County indicates that ~50% of the nitrogen load occurs during dry weather conditions. The baseflow sampling will be used in conjunction with the storm event sampling to partition the annual discharge and pollutant load between baseflow (dry weather) conditions and storm event conditions.

Pollutant loads were examined for each of the baseflow sites. Total Suspended solids were excluded from the baseflow analyses because limited conclusions can be drawn from this parameter during a baseflow sample. Many factors can affect the total suspended solids including small construction projects and car washing. These factors may only affect the stream for the limited time the sample is taken and can be misleading if extrapolated for a longer period of time. The results obtained were standardized to both daily pollutant load for drainage area and a daily load per acre and are shown in table 8-7.

Table 8-7: 2010 Daily Baseflow Pollutant Loads for Scott's Level Branch Sites

Site	Acres	TKN (mg/L)	TKN Daily Load (#s)	TKN Daily Load (#s per acre)	NO_2/NO_3 (mg/L)	NO_2/NO_3 Daily Load (#s)	NO_2/NO_3 Daily load (#s per acre)
SL-00 – Trib.	67	<0.1	N/A	N/A	1.73	9.02	0.1346
SL-01	2,186	0.26	1.47	0.0007	0.63	4.60	0.0021
SL-02	1,908	1.40	1.81	0.0009	0.88	4.37	0.0023
SL-03	1,434	0.31	1.14	0.0008	1.20	3.81	0.0027
SL-04	1,167	0.24	0.87	0.0007	1.02	3.04	0.0026
SL-05 – Trib.	202	0.21	0.07	0.0003	3.02	1.21	0.0060
SL-06	742	0.49	0.60	0.0008	1.40	2.32	0.0031
SL-07 – Trib.	62	0.27	0.09	0.0015	0.85	0.25	0.0040
SL-08	451	0.23	0.40	0.0009	1.38	2.05	0.0045
SL-09 - outfall	15	0.15	0.00	0.0002	2.74	0.02	0.0016
SL-10	265	0.40	0.09	0.0003	1.48	0.48	0.0018

Site	Acres	TN (mg/L)	TN Daily Load (#s)	TN Daily Load (#s per acre)	TP (mg/L)	TP Daily Load (#s)	TP Daily Load (#s per acre)

SL-00 – Trib.	67	<0.016	N/A	N/A	<0.025	N/A	N/A
SL-01	2,186	1.06	6.07	0.0028	<0.025	N/A	N/A
SL-02	1,908	1.12	6.18	0.0032	<0.025	N/A	N/A
SL-03	1,434	1.19	4.95	0.0035	<0.025	N/A	N/A
SL-04	1,167	1.13	3.91	0.0034	<0.025	N/A	N/A
SL-05 Trib.	202	2.49	1.28	0.0063	<0.025	N/A	N/A
SL-06	742	0.99	2.92	0.0039	<0.025	N/A	N/A
SL-07 Trib.	62	1.05	0.34	0.0055	<0.025	N/A	N/A
SL-08	451	1.34	2.45	0.0054	<0.025	N/A	N/A
SL-09 - Outfall	15	4.55	0.03	0.0017	<0.025	N/A	N/A
SL-10	265	1.17	0.57	0.0021	0.047	0.02	0.0001

Site SL-05, a tributary with a drainage area of 202 acres has disproportionately high concentrations of all nutrient parameters. These high concentrations are suspected to be from dog feces. It appears that someone walking his or her dog routinely throws the waste into the stream. Staff have talked to one of the homeowners near the stream and informed the local watershed group, so they may bring it up at any appropriate meetings. Staff will be distributing educational literature throughout the neighborhood.

8.3.2.3 Pollutant Load Calculations

Data from the USGS gage was recorded at 15-minute intervals from October 1, 2005 through December 31, 2010 resulting in 184,127 individual discharge readings. Discharge data from the Win-situ probe installed at the outfall recorded 35,040 15-minute intervals from January 1, 2010 to December 31, 2010. The regression equations determined above from the storm event samples, relating pollutant concentration to discharge, were used to determine the pollutant concentration for each 15-minute interval. From this data the load was calculated for each 15-minute interval using the following formula:

$P_L = (P_C * .000008345) * (CFS * 448.8 * 15)$, where

P_L = Pollutant Load,
P_C = Pollutant Concentration,
.000008345 = Conversion factor to convert mg/L to pounds per gallon,
CFS = Cubic feet per second,
448.8 = Conversion factor to convert cubic feet per second to gallons per minute
15 = number of minutes in the interval.

The results obtained by the above formula were standardized to both an annual pollutant load for the drainage area and an annual pollutant load per acre. In addition, the data were analyzed for seasonal loads, storm event pollutant loads, and the percent of the load delivered during baseflow conditions (Table 8-8).

Table 8-8: Pollutant Load Characteristics for USGS gaged site calendar year 2010

Parameter	Pounds/ Year	Pounds/year Standardized by average rainfall	Pound/Acre Standardized by average rainfall	% by Season	Storm Event lbs.	% Load as Storm Flow	Baseflow lbs.	% Load as Baseflow
TSS								
Fall	53,485	58,829	26.91	20.4%	51,804	96.9%	1,681	3.1%
Winter	113,909	125,291	57.32	43.5%	98,842	86.8%	15,067	13.2%
Spring	69,027	75,924	34.73	26.4%	61,611	89.3%	7,416	10.7%
Summer	25,288	27,814	12.72	9.7%	24,674	97.6%	614	2.4%
Total	**261,708**	**287,858**	**131.68**		**236,931**	**90.5%**	**24,777**	**9.5%**
TKN								
Fall	952	1,047	0.48	20.0%	850	89.3%	101	10.6%
Winter	2,087	2,296	1.05	43.8%	1,546	74.1%	542	25.9%
Spring	1,238	1,362	0.62	26.0%	921	74.4%	318	25.7%
Summer	485	534	0.24	10.2%	442	91.2%	43	8.9%
Total	**4,763**	**5,239**	**2.40**		3,759	**78.9%**	**1,003**	**21.1%**
NO_2/NO_3								
Fall	595	654	0.30	19.3%	457	76.8%	138	23.1%
Winter	1,310	1,441	0.66	42.6%	829	63.3%	482	36.8%
Spring	836	919	0.42	27.2%	509	60.8%	327	39.1%
Summer	336	369	0.17	10.9%	267	79.4%	69	20.5%
Total	**3,077**	**3,384**	**1.55**		**2,061**	**67.0%**	**1,016**	**33.0%**
TN								
Fall	1,637	1,800	0.82	19.7%	1,405	85.8%	232	14.2%
Winter	3,627	3,989	1.82	43.7%	2,551	70.3%	1,076	29.7%
Spring	2,184	2,402	1.10	26.3%	1,521	69.7%	663	30.3%
Summer	859	945	0.43	10.3%	755	87.9%	104	12.1%
Total	**8,307**	**9,137**	**4.18**		**6,232**	**75.0%**	**2,074**	**25.0%**
TP								
Fall	165	182	0.08	20.4%	155	94.0%	10	6.1%
Winter	354	390	0.18	43.8%	286	80.7%	69	19.4%
Spring	210	231	0.11	25.9%	173	82.2%	37	17.6%
Summer	81	89	0.04	10.0%	77	94.8%	4	4.8%
Total	**809**	**890**	**0.41**		**690**	**85.3%**	**120**	**14.8%**
Total Copper								
Fall	10.2	11.3	0.0052	20.1%	9.3	91.3%	0.9	9.1%
Winter	22.3	24.5	0.0112	43.8%	17.0	76.0%	5.3	24.0%
Spring	13.2	14.5	0.0066	25.9%	10.1	76.7%	3.1	23.1%
Summer	5.1	5.7	0.0026	10.1%	4.8	93.4%	0.4	7.5%
Total	**50.9**	**55.9**	**0.0256**		**41.2**	**80.8%**	**9.7**	**19.1%**
Total Lead								
Fall	3.7	4.0	0.0018	20.5%	3.5	95.3%	0.1	3.9%
Winter	7.8	8.6	0.0039	43.6%	6.6	85.0%	1.2	15.3%
Spring	4.7	5.2	0.0024	26.1%	4.1	86.9%	0.6	12.9%
Summer	1.8	1.9	0.0009	9.8%	1.7	94.5%	0.1	3.0%
Total	**17.9**	**19.7**	**0.0090**		**15.9**	**89.1%**	**2.0**	**11.2%**

Parameter	Pounds/ Year	Pounds/year Standardized by average rainfall	Pound/Acre Standardized by average rainfall	% by Season	Storm Event lbs.	% Load as Storm Flow	Baseflow lbs.	% Load as Baseflow

Total Zinc								
Fall	26.9	29.6	0.0135	20.4%	25.5	94.7%	1.4	5.3%
Winter	57.5	63.3	0.0290	43.7%	47.2	82.0%	10.4	18.0%
Spring	34.1	37.6	0.0172	25.9%	28.7	84.1%	5.5	16.1%
Summer	13.1	14.4	0.0066	9.9%	12.5	95.4%	0.5	4.2%
Total	**131.6**	**144.7**	**0.0662**		**113.8**	**86.5%**	**17.8**	**13.5%**
Sodium								
Fall	40,977	45,072	20.62	19.4%	32,012	78.1%	8,966	21.9%
Winter	90,615	99,669	45.59	42.8%	58,067	64.1%	32,548	35.9%
Spring	57,270	62,992	28.82	27.0%	35,446	61.9%	21,824	38.1%
Summer	22,900	25,188	11.52	10.8%	18,469	80.7%	4,431	19.3%
Total	**211,762**	**232,922**	**106.55**		**143,994**	**68.0%**	**67,768**	**32.0%**
Chloride								
Fall	47,040	51,740	23.67	19.3%	34,936	74.3%	12,104	25.7%
Winter	102,692	112,953	51.67	42.1%	63,198	61.5%	39,494	38.5%
Spring	66,782	73,455	33.60	27.4%	39,296	58.8%	27,486	41.2%
Summer	27,164	29,879	13.67	11.1%	20,897	76.9%	6,268	23.1%
Total	**243,678**	**268,027**	**122.61**		**158,327**	**65.0%**	**85,351**	**35.0%**

Table 8-8b: Pollutant Load Characteristics for Outfall site (SL-09) calendar year 2010

Parameter	Pounds/ Year	Pounds/year Standardized by average rainfall	Pound/Acre Standardized by average rainfall	% by Season	Storm Event lbs.	% Load as Storm Flow	Baseflow lbs.	% Load as Baseflow
TSS								
Fall	305	345	23.00	17.8%	292	95.7%	13	4.2%
Winter	547	620	41.33	32.0%	354	64.6%	193	35.3%
Spring	547	620	41.33	32.0%	474	86.7%	73	13.3%
Summer	310	351	23.40	18.2%	304	97.9%	7	2.1%
Total	**1,709**	**1,936**	**129.07**		**1,423**	**83.3%**	**285**	**16.7%**
TKN								
Fall	14	16	1.07	16.5%	12	88.3%	2	13.6%
Winter	38	43	2.87	43.6%	22	58.2%	16	41.0%
Spring	24	27	1.80	28.0%	17	70.1%	7	31.0%
Summer	10	12	0.80	12.0%	9	92.5%	1	11.2%
Total	**87**	**98**	**6.53**		**61**	**69.6%**	**26**	**29.9%**
NO_2/NO_3								
Fall	5	6	0.40	16.1%	4	87.1%	1	17.3%
Winter	15	17	1.13	45.2%	8	56.1%	6	41.4%
Spring	9	10	0.67	27.6%	6	64.7%	3	34.6%
Summer	4	4	0.27	11.0%	3	76.4%	1	13.0%
Total	**32**	**37**	**2.47**		**22**	**67.7%**	**11**	**33.5%**
TN								
Fall	21	24	1.60	16.4%	18	85.3%	3	14.2%
Winter	56	64	4.27	44.1%	33	58.7%	23	41.9%
Spring	36	40	2.67	27.9%	24	67.3%	11	31.5%
Summer	15	17	1.13	11.7%	13	87.6%	2	11.8%
Total	**128**	**145**	**9.67**		**88**	**68.9%**	**40**	**30.9%**
Parameter	**Pounds/ Year**	**Pounds/year Standardized by average rainfall**	**Pound/Acre Standardized by average rainfall**	**% by Season**	**Storm Event lbs.**	**% Load as Storm Flow**	**Baseflow lbs.**	**% Load as Baseflow**

TP								
Fall	2	2	0.13	16.7%	1.9	94.3%	0.2	12.5%
Winter	5	6	0.40	42.4%	3.2	64.5%	2.2	44.1%
Spring	4	4	0.27	28.3%	2.6	65.1%	1.0	25.5%
Summer	2	2	0.13	12.6%	1.5	73.5%	0.1	7.2%
Total	**13**	**15**	**1.00**		**9.2**	**70.6%**	**3.6**	**27.8%**
Total Copper								
Fall	0.15	0.17	0.0113	16.7%	0.13	89.0%	0.02	12.0%
Winter	0.39	0.44	0.0293	42.5%	0.23	58.8%	0.16	40.3%
Spring	0.26	0.29	0.0193	28.3%	0.18	70.7%	0.07	28.1%
Summer	0.11	0.13	0.0087	12.5%	0.10	94.2%	0.01	9.4%
Total	**0.91**	**1.03**	**0.0687**		**0.65**	**71.5%**	**0.26**	**28.4%**
Total Lead								
Fall								
Winter	0.04	0.05	0.0033	16.7%	0.036	89.1%	0.005	11.4%
Spring	0.10	0.11	0.0073	42.1%	0.060	60.3%	0.041	41.0%
Summer	0.07	0.08	0.0053	28.4%	0.049	70.5%	0.019	26.9%
Total	0.03	0.03	0.0020	12.8%	0.028	93.5%	0.003	8.7%
	0.24	**0.27**	**0.0180**		0.173	**72.2%**	**0.067**	**27.9%**
Total Zinc								
Fall								
Winter	0.41	0.46	0.0307	16.9%	0.36	89.0%	0.04	10.2%
Spring	0.99	1.13	0.0753	41.3%	0.60	60.3%	0.40	40.2%
Summer	0.69	0.78	0.0520	28.6%	0.51	74.1%	0.18	25.9%
Total	0.32	0.36	0.0240	13.2%	0.30	92.3%	0.02	7.4%
	2.41	**2.73**	**0.1820**		**1.77**	**73.4%**	**0.64**	**26.7%**
Sodium								
Fall	258	292	19.47	15.7%	199	77.1%	59	22.7%
Winter	774	877	58.47	47.1%	432	55.8%	342	44.2%
Spring	449	509	33.93	27.3%	263	58.6%	186	41.4%
Summer	163	185	12.33	9.9%	126	77.5%	37	22.7%
Total	**1,644**	**1,863**	**124.20**		**1,020**	**62.0%**	**624**	**38.0%**
Chloride								
Fall	164	186	12.40	16.3%	140	85.4%	24	14.6%
Winter	445	504	33.60	44.3%	259	58.2%	186	41.8%
Spring	280	317	21.13	27.8%	189	67.5%	91	32.3%
Summer	116	132	8.80	11.6%	102	87.9%	14	12.3%
Total	**1,005**	**1,139**	**75.93**		**690**	**68.7%**	**315**	**31.3%**

There are distinct seasonal differences in the delivery of nutrient and total suspended solids pollutant loads at SL-01 and SL-09, with summer being the season of reduced load delivery for all pollutants analyzed. At SL-01, Approximately 28% of the precipitation fell during the summer season, but only 14.6% of this precipitation was reflected in the stream flow (Table 8-5). At SL-09, 23.5% of the precipitation fell during the summer, but only 9.3% was reflected in the stream flow. The abundance of plants in the summertime means an increase in evapotranspiration, which accounted for most of the runoff from precipitation. This summer decrease in stream flow results in a decrease in the delivery of pollutants.

At SL-01, baseflow accounts for a negligible amount of the pollutant load delivery for Total Suspended Solids (9.5%), Total Phosphorus (14.8%), Total Zinc (13.5%), and Total Lead (11.2%). At SL-09, about one-third of the pollutant loads are delivered during baseflow. The

exception is TSS, which only has 16.7% of the load delivered at baseflow. At SL-01, Total Nitrogen has 25% of its load delivered as baseflow. The Nitrite/Nitrate, Sodium, and Chloride have about one-third of their load delivered as baseflow. TKN (ammonia and organic nitrogen) has 21.1% of its load delivered during baseflow conditions. Organic nitrogen will be mobilized both within the stream channel and washed into the stream during storm events.

Figure 8-6 shows pollutant loads for TN, TP and TSS at the SL-01 gage throughout the years. This data is adjusted for average annual rainfall.

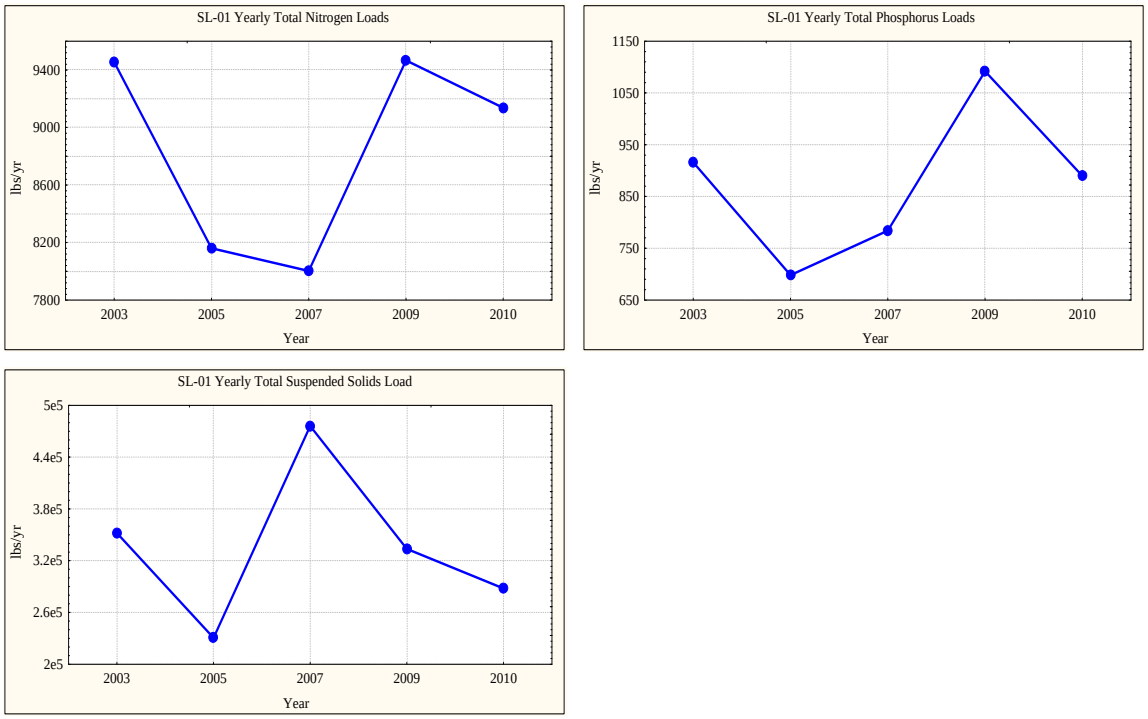


Figure 8-6: Scotts Level Branch pollutant loads at SL-01 gage from 2003-2010 (adjusted for average annual rainfall)

8.3.3 Geomorphological Monitoring Results

Streambank Soil Sampling: Nine sets (3 Powder Mill, 6 Scott's Level) of Stream bank and bed core samples have been collected in the vicinity of the permanent cross sections for laboratory analysis of bulk density, particle size distribution, total nitrogen, and total phosphorus and other constituents. Eventually, it is planned to sample each of the 30 cross sections of both streams. The samples will be one-time sample collections, with 10% of the sites, randomly selected, for a second round of sample collection to provide an analysis of annual variability. The data from each cross section will allow either positive or negative loading estimates to be made for the cross sections. These estimates, if extended to represent their respective stream segments, may provide information helpful in understanding the sediment and chemical flux of the stream system. Based on the annual and long term change, and the results of the core samples, the estimated annual sediment, total nitrogen, and total phosphorus loads will be calculated for comparison with the chemical monitoring results derived from the in-stream monitoring site.

8.3.3.1 Scotts Level Branch Geomorphological Monitoring Results: The cross-sectional morphology of the 18 cross sections was examined to show changes that occurred in 2010-2011

and 2006-2011. Figure 8-7 shows an overlay of CX #1 for 2010 and 2011. Table 8-9 presents the amount of aggradation (filling) or degradation (cutting) within the active channel, and Table 8-10 (listed from upstream to downstream) summarizes Table 8-9. Data in Table 8-9 were annualized to standardize aggradation and degradation estimates. The data files and plots are included on the CD accompanying this report. Most reaches showed small adjustments in cut and fill between 2010 and 2011.

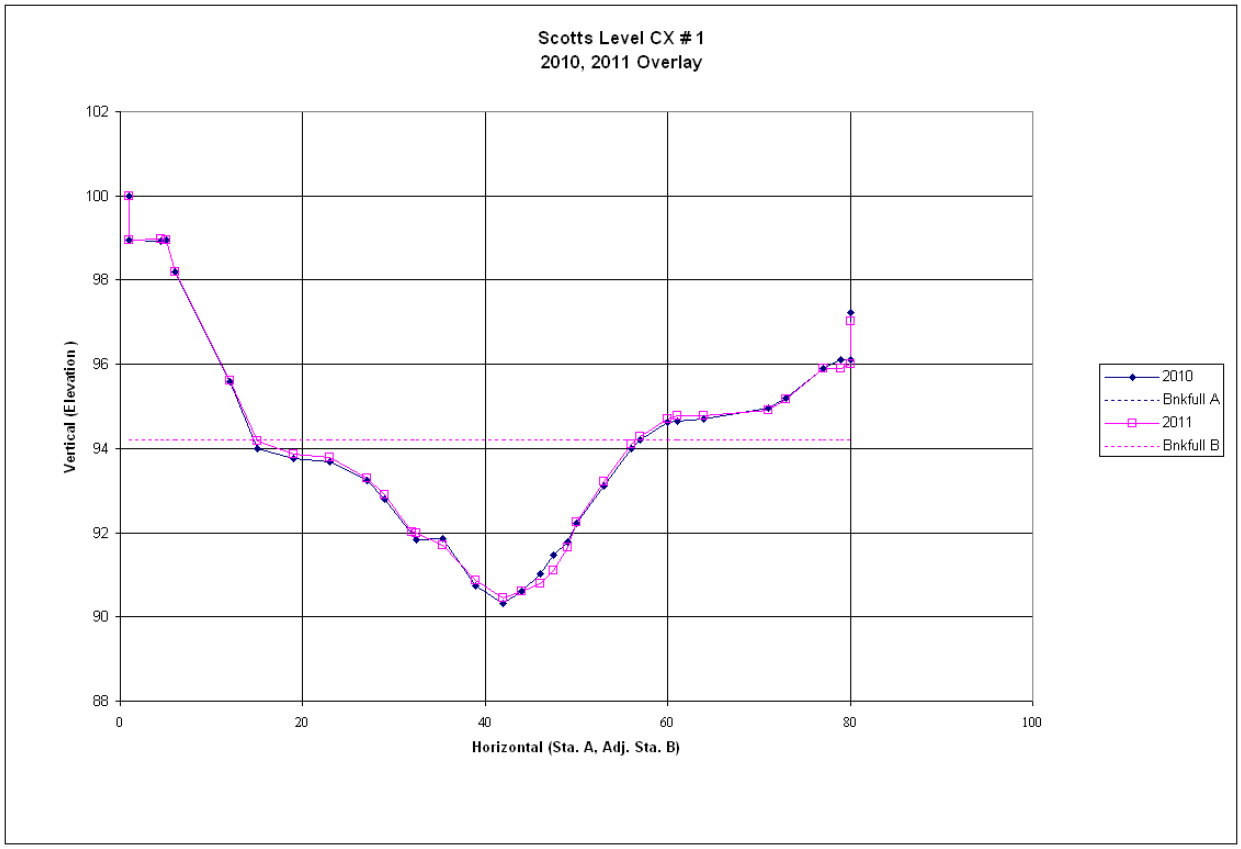


Figure 8-7: Scotts Level Branch Geomorphological Cross Section 1 Overlay showing differences in channel morphology between the 2010 and 2011 surveys.

Impervious land cover influences the majority of the Scotts Level Branch hydrology. Therefore the sediment fluxes within the stream channel are most likely part of the process of the stream reworking its surrounding legacy flood plain sediments and ultimately transporting them into the Gwynns Falls mainstem and beyond. The baseline data will be useful in evaluating the stream restoration project at McDonogh Road. The project will stabilize the stream channel and reconnect the stream to the floodplain.

Table 8-9: Scotts Level Branch Cross Sections - Annualized Cut and Fill Amounts

SL20: Change (cu ft)	Period:2010-2011	Period: 2006-2011	SL10: Change (cu ft)	Period:2010-2011	Period: 2006-2011
Total Cut	-0.3	0.0	Total Cut	-1.6	-0.6
Total Fill	1.0	0.7	Total Fill	0.3	0.3
Total Change	1.3	0.7	Total Change	1.9	0.9
Net Change	0.7	0.7	Net Change	-1.3	-0.3
SL19: Change (cu ft)	**Period:2010-2011**	**Period: 2006-2011**	**SL9: Change (cu ft)**	**Period:2010-2011**	**Period: 2006-2011**
Total Cut	-0.4	-0.1	Total Cut	-0.4	-2.0
Total Fill	1.9	1.1	Total Fill	1.9	0.2
Total Change	2.3	1.2	Total Change	2.3	2.2
Net Change	1.5	1.0	Net Change	1.5	-1.8
SL18: Change (cu ft)	**Period:2010-2011**	**Period: 2006-2011**	**SL8: Change (cu ft)**	**Period:2010-2011**	**Period: 2006-2011**
Total Cut	-1.4	-0.6	Total Cut	-0.6	-0.2
Total Fill	2.7	1.0	Total Fill	1.1	0.4
Total Change	4.1	1.6	Total Change	1.7	0.6
Net Change	1.3	0.4	Net Change	0.5	0.2
SL17: Change (cu ft)	**Period:2010-2011**	**Period: 2006-2011**	**SL7: Change (cu ft)**	**Period:2010-2011**	**Period: 2006-2011**
Total Cut	-3.3	-0.8	Total Cut	-0.7	-0.6
Total Fill	0.2	0.1	Total Fill	1.3	0.5
Total Change	3.5	0.9	Total Change	2.0	1.1
Net Change	-3.1	-0.7	Net Change	0.6	-0.1
SL16: Change (cu ft)	**Period:2010-2011**	**Period: 2006-2011**	**SL6: Change (cu ft)**	**Period:2010-2011**	**Period: 2006-2011**
Total Cut	-0.6	-0.3	Total Cut	-1.8	-0.2
Total Fill	1.0	0.4	Total Fill	0.3	0.4
Total Change	1.6	0.7	Total Change	2.1	0.6
Net Change	0.4	0.1	Net Change	-1.5	0.2
SL15: Change (cu ft)	**Period:2010-2011**	**Period: 2006-2011**	**SL5: Change (cu ft)**	**Period:2010-2011**	**Period: 2006-2011**
Total Cut	-0.5	-0.4	Total Cut	NA	NA
Total Fill	1.1	0.2	Total Fill	NA	NA
Total Change	1.6	0.6	Total Change	NA	NA
Net Change	0.6	-0.2	Net Change	NA	NA
SL14: Change (cu ft)	**Period:2010-2011**	**Period: 2006-2011**	**SL4: Change (cu ft)**	**Period:2010-2011**	**Period: 2006-2011**
Total Cut	-0.7	-1.4	Total Cut	NA	NA
Total Fill	0.8	0.9	Total Fill	NA	NA
Total Change	1.5	2.3	Total Change	NA	NA
Net Change	0.1	-0.5	Net Change	NA	NA

SL13: Change (cu ft)	Period:2010-2011	Period: 2006-2011	SL3: Change (cu ft)	Period:2010-2011	Period: 2006-2011

Total Cut	-0.6	-0.7	Total Cut	-0.5	0.0
Total Fill	2.8	1.3	Total Fill	0.3	0.3
Total Change	3.4	2.0	Total Change	0.8	0.3
Net Change	2.2	0.6	Net Change	-0.2	0.3
SL12: Change (cu ft)	**Period:2010-2011**	**Period: 2006-2011**	**SL2: Change (cu ft)**	**Period:2010-2011**	**Period: 2006-2011**
Total Cut	-3.1	-8.0	Total Cut	-2.3	-0.6
Total Fill	0.9	9.0	Total Fill	1.9	0.4
Total Change	4.0	17.0	Total Change	4.2	1.0
Net Change	-2.2	1.0	Net Change	-0.4	-0.2
SL11: Change (cu ft)	**Period:2010-2011**	**Period: 2006-2011**	**SL1: Change (cu ft)**	**Period:2010-2011**	**Period: 2006-2011**
Total Cut	-2.6	-0.5	Total Cut	-1.4	-0.7
Total Fill	0.3	0.3	Total Fill	2.6	3.1
Total Change	2.9	0.8	Total Change	4.0	3.8
Net Change	-2.3	-0.2	Net Change	1.2	2.4

* Permission from private property owners for sampling SL 5 and SL 4 has not yet been obtained, therefore there are no results.

Table 8-10: Scotts Level Branch Stream Channel Changes Over Time.

SL #	CX 2010-2011	CX 2006-2011
20	sa	sa
19	sa	sa
18	sa	sa
17 (Trib.)	d	sd
16	sa	sa
15	sa	sd
14	sa	sd
13	a	sa
12	a	sa
11	d	sd
10	sd	sd
9	sa	sd
8	sa	sa
7	sa	sd
6	sd	sa
5	NA	NA
4	NA	NA
3	sd	sa
2	sd	sd
1	sa	a

Symbols: a: aggradation, d: degradation, sa:slight aggradation, sd:slight degradation

8.3.3.2 Powder Mill Run Geomorphological Monitoring Results: Cross-sectional measurements for 2010 and 2011, and 2006 and 2011, were compared to determine changes in bedload movement. The data files and plots are included on the CD accompanying this report. Table 8-11 presents cubic feet of aggradation (filling) and degradation (cutting) within the active channel of each cross section. Table 8-12 summarizes Table 8-11. The Powder Mill Run channel

remained active, especially at the lower (CX 1) and upper (CX 10) limits of the study area. A headcut began during late spring or summer 2009, just upstream of CX 1, which resulted in a large amount of channel material filling the cross section. Heavy rainfall (approximately 14 inches above average, as measured at BWI) and scouring stream flows were the likely cause of the headcut at CX 1, as well as the bedload movement at the other cross sections. The headcut continued through 2010 and exposed a concrete sewer line casing early in 2011. The middle and upper reaches of Powder Mill Run lost channel material between 2010 and 2011. The imperviousness of the upstream channel likely concentrates high flows and causes downstream channel instability.

Table 8-11: Powder Mill Run Cross Sections - Cut and Fill Amounts

PM 10:Change (cu ft)	Period:2010-2011	Period: 2006-2011		PM 5:Change (cu ft)	Period:2010-2011	Period: 2006-2011
Total Cut	-11.0	-0.9		Total Cut	-7.5	-2.4
Total Fill	0.1	0.6		Total Fill	2.2	0.8
Total Change	11.1	1.5		Total Change	9.7	3.2
Net Change	-10.9	-0.3		Net Change	-5.3	-1.6
PM 9:Change (cu ft)	**Period:2010-2011**	**Period: 2006-2011**		**PM 4:Change (cu ft)**	**Period:2010-2011**	**Period: 2006-2011**
Total Cut	-2.9	-0.9		Total Cut	-9.1	-1.1
Total Fill	0.5	1.2		Total Fill	0.5	0.5
Total Change	3.4	2.1		Total Change	9.6	1.6
Net Change	-2.4	0.3		Net Change	-8.6	-0.6
PM 8:Change (cu ft)	**Period:2010-2011**	**Period: 2006-2011**		**PM 3:Change (cu ft)**	**Period:2010-2011**	**Period: 2006-2011**
Total Cut	-2.8	-0.7		Total Cut	-6.9	-0.6
Total Fill	1.7	0.4		Total Fill	0.2	0.4
Total Change	4.5	1.1		Total Change	7.1	1.0
Net Change	-1.1	-0.3		Net Change	-6.7	-0.2
PM 7:Change (cu ft)	**Period:2010-2011**	**Period: 2006-2011**		**PM 2:Change (cu ft)**	**Period:2010-2011**	**Period: 2006-2011**
Total Cut	-5.1	-0.8		Total Cut	-1.8	-0.4
Total Fill	0.3	0.1		Total Fill	2.8	0.7
Total Change	5.4	0.9		Total Change	4.6	1.1
Net Change	-4.8	-0.7		Net Change	1.0	0.3
PM 6:Change (cu ft)	**Period:2010-2011**	**Period: 2006-2011**		**PM 1:Change (cu ft)**	**Period:2010-2011**	**Period: 2006-2011**
Total Cut	-3.4	-0.5		Total Cut	-7.0	-2.9
Total Fill	1.1	1.0		Total Fill	7.0	4.0
Total Change	4.5	1.5		Total Change	14.0	6.9
Net Change	-2.3	0.5		Net Change	0.0	1.1

Table 8-12: Powder Mill Run, 2008-2009 and 2005-2009 Stream Channel Changes

PM #	CX 2010-2011	CX 2006-2011

10	d	sd
9	d	sa
8	sd	sd
7	d	sd
6	d	sa
5	d	sd
4	d	sd
3	d	sd
2	sa	sa
1	nc	sa

Symbols: a: aggradation, d: degradation, sa :slight aggradation, sd :slight degradation, nc: no change

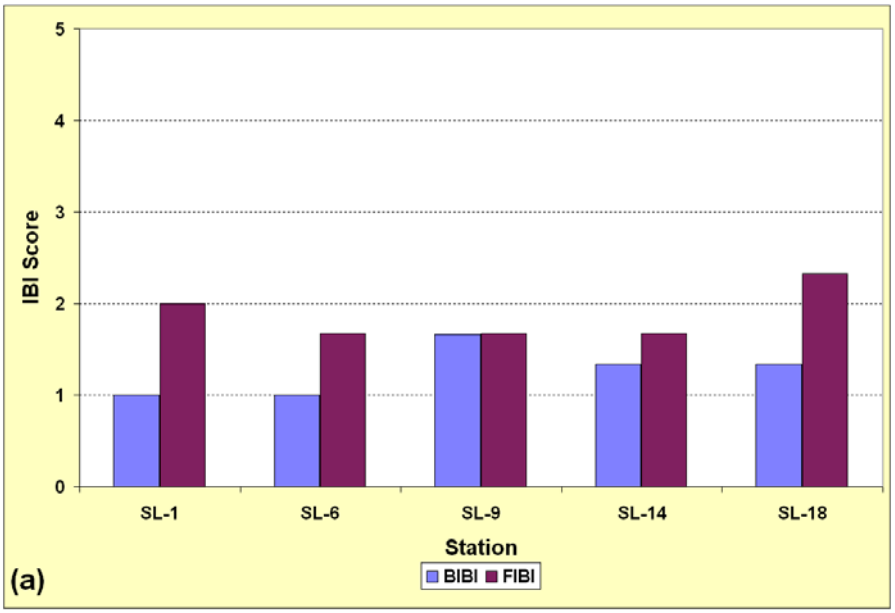
8.3.4 Biological Monitoring Results

Benthic macroinvertebrate and fish sampling were conducted as per MBSS protocols. Benthic macroinvertebrates were sampled between March 8th and April 1st, 2010 and fish were sampled between June 15th and August 3rd , 2010. Scotts Level Branch was sampled at SL-1, SL-6, SL-9, SL-14, and SL-18. Powder Mill Run was sampled at PM-1, PM-4, and PM-9. The Benthic Index of Biotic Integrity (BIBI) and Fish Index of Biotic Integrity (FIBI) were calculated using metrics developed by MBSS for Piedmont streams. The BIBI and FIBI scoring criteria are: 1.00-1.99 (Very Poor), 2.00-2.99 (Poor), 3.00-3.99 (Fair), and 4.00-5.00 (Good). Stream physical habitat was assessed when macroinvertebrates and fish were collected using the MBSS Physical Habitat Index. The protocol measured components of stream physical habitat, including fish habitat quality, macroinvertebrate habitat quality, stream depth and velocity diversity, riffle quality, pool quality, the percentage of sediment surrounding stream bottom substrates, and the percentage of shading in the stream reach. Each parameter was estimated on a scale of 0-20, except for sediment and shading, which were percentage estimates. Physical habitat data were converted to physical habitat index (PHI) scores and rated using criteria from Southerland et al (2005). Minimally degraded stations had PHI scores of 81-100, partially degraded stations had PHI scores of 66-80, degraded stations had PHI scores of 51-65, and severely degraded stations had PHI scores of 0-50.

The IBI scores are shown in Figure 8-8. All BIBIs were in the Very Poor condition category. The FIBI scores for all sites in Scotts Level were Poor or Very Poor. The FIBI scores in Powder Mill were Poor at PM-1 and PM-4 and Very Poor at PM-9. Fish IBI scores were all higher then BIBI scores. Fish in both Scotts Level Branch and Powder Mill Run are better able than benthic macroinvertebrates to survive the acute and chronic water quality problems within both streams. The mobility of fish likely allows them to better exploit good habitat and avoid such episodic events as high storm flows. The PHI scores are shown in Figure 8-9. Scotts Level Branch physical habitat condition was degraded at SL-1, and severely degraded at all other stations. Powder Mill Run physical habitat was severely degraded at PM-1 and PM-9, and degraded at PM-4.

The benthic and fish communities of Scotts Level Branch and Powder Mill Run show the effects of environmental stress. Both are low in diversity and are primarily composed of pollution tolerant organisms. Stream habitat is degraded and provides poor living space for both benthos and fish. Results of biological monitoring have been consistent since monitoring began in 2005,

which suggests that the baseline biological condition has been identified. These baseline data will be useful in monitoring and identifying the effects of stream restoration.



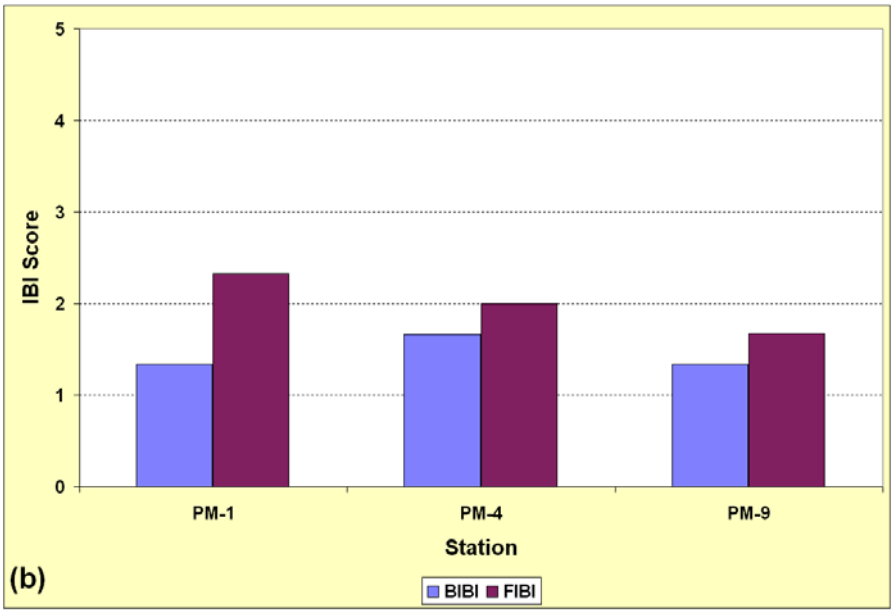


Figure 8-8: (a) Scotts Level Branch and (b) Powder Mill Run IBI Scores. Note: A BIBI could not be calculated for PM-1 because only 10 organisms were collected from the 75-m reach. Fish were collected from PM-9, which is downstream of station PM-10, due to a human waste contamination issue at PM-10.

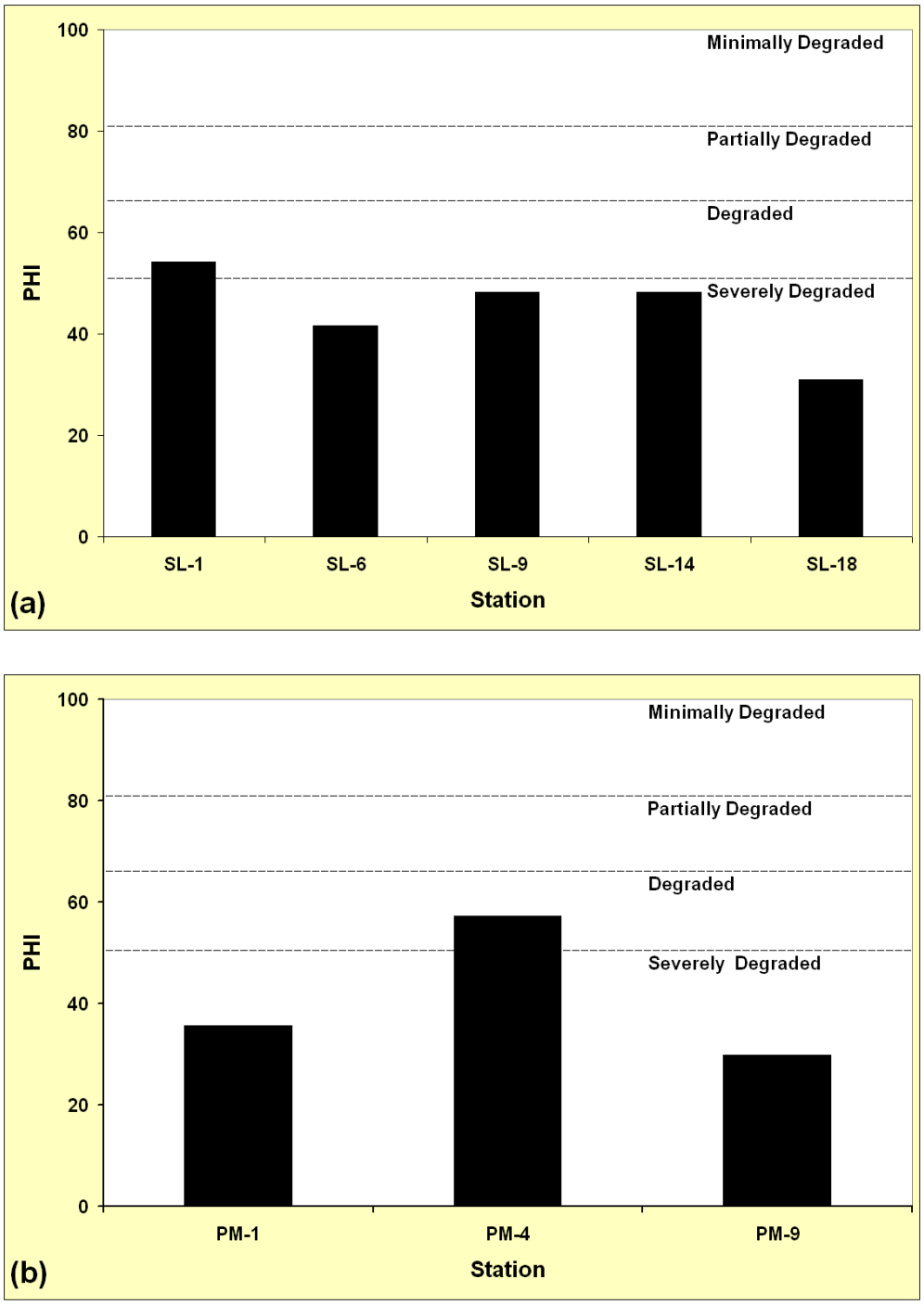


Figure 8-9: (a) Scotts Level Branch and (b) Powder Mill Run PHI Scores

8.3.5 Scotts Level Branch Pollutant Load Calculations

Integrating geomorphology, stream bank soil chemistry, and water chemistry data, allows examination of pollutant loads for various components of the Scotts Level Branch watershed. The three components of the field model are in-stream water quality loads measured at SL-01, stream bank soil loads measured at the geomorphology cross-sections, and watershed wash-off

loads measured at outfall SL-09. The model expectation is that in-stream water quality estimates are equal to the sum of stream bank and watershed wash-off estimates.

Stream Erosion Loads

The calculations for the stream erosion loads are based on the stream channel changes measured by the annual cross-sections and the mean concentration of TKN, NO_3, and TP determine by stream bank and bed chemical analysis. The net change at a particular cross-section was applied to a stream length based on the midpoints between cross-sections to determine the cubic feet of change for the stream reach. The load for each reach was then calculated based on the average bulk density of stream bank and bed samples, the chemical concentrations of nitrogen species, and total phosphorus. The numbers used in this analysis were:

- Mean Bulk Density = 60.7 lbs/ft^3
- Mean TKN Concentration = 0.002254 lbs/lb sediment
- Mean NO_3 Concentration = 0.00005 lbs/lb sediment
- Mean TP Concentration = 0.000705 lbs/lb sediment

The following formulas were applied to determine the stream channel erosion loads for sediment, TKN, TP, NO_3, and TN

Sediment Load = Net Change Cross-section (ft^2) x reach length (ft) x Bulk Density (lbs/ft^3)

Total TKN Load = Sediment Weight (lbs) x Mean TKN Concentration

Total NO_3 Load = Sediment Weight (lbs) x Mean NO_3 Concentration

Total TP Load = Sediment Weight (lbs) x Mean TP Concentration

Total TN Load = Total TKN Load + Total NO_3 Load

Table 8-13 shows load calculations derived from the geomorphology measurements for the calendar year 2010.

Table 8-13: 2010 Pollutant Load Estimates and Calculations for Stream Bank Soil Sediment and Nutrients

Site	Stream Length (ft)	Distance Between Sites	Adjusted Stream Length[1]	Net Cut/Fill at Site (cu ft)[2]	Cut/Fill Adjusted for Stream Length (cu ft)[3]	Sediment Weight (lbs)[4]	TKN (lbs)[5]	TP (lbs)[6]	NO_3 (lbs)[7]	TN (lbs)[8]
20	885	* [9]	1,643	0.7	1,150	69,826	157	49	0.3	158
19	2,402	1,517	1,351	1.5	2026	123,009	277	87	0.6	278
18	3,587	1,185	3,434	1.3	4,464	270,981	611	191	1.4	612
17	2,782	* [10]	3,662	-3.1	-11,352	-689,079	-1,553	-485	-3.4	-1,557
16	12,932	5,683	3,918	0.4	1,567	95,131	214	67	0.5	215
15	15,085	2,153	2,269	0.6	1,361	82,637	186	58	0.4	187
14	17,470	2,385	1,738	0.1	174	10,547	24	7	0.1	24
13	18,560	1,090	3,070	2.2	6,753	409,901	924	289	2.0	926

Site	Stream Length (ft)	Distance Between Sites	Adjusted Stream Length[1]	Net Cut/Fill at Site (cu ft)[2]	Cut/Fill Adjusted for Stream Length (cu ft)[3]	Sediment Weight (lbs)[4]	TKN (lbs)[5]	TP (lbs)[6]	NO_3 (lbs)[7]	TN (lbs)[8]
12	1,575	* [10]	1,601	2.5	4,002	242,952	548	171	1.2	549
11	25,210	5,049	3,764	-2.3	-8,656	-525,422	-1,184	-370	-2.6	-1,187
10	27,688	2,478	2,400	-1.3	-3,120	-189,384	-427	-133	-0.9	-428
9	30,010	2,322	2,562	1.5	3,843	233,270	526	164	1.2	527
8	32,812	2,802	6,845	0.5	3,422	207,731	468	146	1.0	469
7	43,699	10,887	6,922	0.6	4,153	252,081	568	178	1.3	569
6	46,655	2,956	4,113	-1.5	-6,170	-374,489	-844	-264	-1.9	-846
Total Load (lbs)	--	--	28,207	--	--	219,692	--	155	--	496
Total Load, Normalized for Rainfall (lbs)	--	--	--	--	--	**241,643**	--	**170**	--	**546**

[1] Stream length upstream of cross-section plus one-half the distance between cross-sections
[2] As calculated from geomorphic cross-section measurements
[3] Geomorphic cut/fill multiplied by adjusted stream length
[4] Cut/fill adjusted for stream length multiplied by 60.7 lb/cu ft (mean bulk density of Scotts Level soils)
[5] Weight of sediment in lbs multiplied by 0.002254 (mean soil TKN in lb/lb sediment)
[6] Weight of sediment in lbs multiplied by 0.000705 (mean soil TP in lb/lb sediment)
[7] Weight of sediment in lbs multiplied by 0.00005 (mean soil NO_3 in lb/lb sediment)
[8] TKN (lbs) plus NO_3 (lbs)
[9] Upstream limit of study. "Distance between sites" does not apply.
[10] Tributary. "Distance between sites" does not apply.

Watershed Load

The land surface pollutant load (measured at the outfall) could only be calculated for 2010, as this was the first year when reliable water chemistry data and discharge were collected for the outfall (SL-09). A flow-rating curve developed by the United States Geological Survey aided in calculating watershed wash-off loads at the SL-09 outfall. The calculated per acre loading rates from the outfall SL-09 were used to calculate the watershed load. The load was determined by placing the watershed acreage (watershed determined by drainage area to SL-01) into four categories:

- Acreage of urban land draining untreated to outfalls,
- Acreage of urban land draining to stormwater management facilities and receiving some treatment,
- Acreage of urban land that did not flow to a storm drain system (considered sheet flow to buffer), and
- Acreage in forest cover based on MDP 2007 land use and CBP Watershed Model 5.2 loading from forest.

Using the pollutant loading information provided in Table 8-8b on the standardized per acre loading rates (standardization based on average annual rainfall), the watershed per acre loads for Total Nitrogen, Total Phosphorus, and Total Suspended Solids were calculated. The respective loading rates were:

- 9.67 lbs/acre Total Nitrogen
- 1.00 lbs/acre Total Phosphorus
- 129.07 lbs/acre Total Suspended Solids

The acreages, nutrient loads, and sediment load by landscape category are shown in Table 8-14.

Table 8-14: Calculated Watershed Loads Delivered Based on SL-09 Monitoring Data

Landscape Category	Acres	TN Load	TP Load	Sediment Load
Untreated Outfalls	1,510.9	14,610	1,511	195,012
Stormwater Management	249.4	1,790	288	18,518
Sheet Flow to Buffer	127.1	184	19	820
Forest Cover	298.3	421	6	24,190
Total	**2,185.7**	**17,005**	**1,824**	**238,540**

The bulk of the nutrient and sediment loads from the watershed are delivered untreated directly to the stream through storm drain outfalls, and a smaller portion of the drainage receives some treatment from stormwater management facilities.

The calculated watershed loads (Table 8-14) were combined with estimated stream erosion loads (Table 8-13) to provide an estimate of the total load delivered to the in-stream monitoring site SL-01. The estimated total load was compared to the calculated (based on discharge and pollutant concentration) load from the monitoring data at SL-01 for 2010. The differences between the two loads were then calculated on both a pound and percentage basis. All loads are standardized to an average precipitation year. The results are displayed in Table 8-15.

Table 8-15: 2010 Watershed Pollutant Load Estimates Compared to Water Quality Monitoring at SL-01

Year	Component	Parameter		
		TN	TP	Sediment
2010	**Geomorphology Pollutant Load (lbs/yr)**	546	170	241,643
	Land Surface Pollutant Load (lbs/yr)	17,005	1,824	238,540
	Total Estimated Watershed Load to SL-01	**17,551**	**1,994**	**480,183**
	In-stream Water Quality Pollutant Load (lbs/yr) SL-01 - Measured	9,136	896	287,813
	Difference Between Estimated Load and Measured	8,415	1,098	192,370
	Percent Underestimate by In-stream Monitoring	**47.9%**	**55.1%**	**40.1%**

The in-stream monitoring site SL-01 measured pollutant loads were 40% - 55% less than the calculated loads based on the geomorphological and the outfall monitoring, site SL-09.

Several explanations may account for why the in-stream monitoring, and stream erosion estimates and land surface (based on outfall SL-09 monitoring) pollutant loads are out of balance.

- The estimates may not be accurate due to inadequate data. The estimates should become more refined as more data are collected annually.
- The outfall is not representative of each outfall in the watershed. This outfall has groundwater input whereas many of the other outfalls are dry.
- Geomorphology estimates are based on once-annual cross-sectional measurements. Although the loads are annualized, they are point-in-time estimates and may not accurately characterize the amount of material being moved through the channel in each study reach over the entire year.
- Soils have not yet been collected at all cross sections. Therefore, the soil data may not be representative of actual pollutant concentrations along the length of Scotts Level Branch.
- Randomly selected cross-sections may not be located to accurately reflect nutrient and sediment fluxes within the Scotts Level Branch watershed.
- Field-measured pollutant loads do not fully integrate stormwater management reductions. Samples for this analysis are collected during storm-flow. Stormwater management facilities retain water for treatment, so that the water wouldn't be released and flow past the gage until several days after sampling.
- The field-collected data may underestimate the in-stream pollutant loads, or the land surface pollutant loads may be overestimated. There may be a component of the in-stream load that our current monitoring is missing. For example, we may not be getting enough peak flow water quality data or we may be missing bed load, or large organic matter. The land surface loads may be overestimated because the SL-09 outfall is not representative of all outfalls in the watershed, as explained above.
- Scotts Level Branch benthic and fish communities are impaired, as shown in past EPS NPDES reports. Nutrient uptake by stream organisms is probably less than in a healthy, functional stream. However, it is likely that some ecosystem function such as, denitrification, floodplain deposition and in-stream biological uptake is maintained and may account for some of the difference between the in-stream measured loads and the estimated loads.
- Some of the bank load may not be accounted for in the in-stream samples. The ISCO sampler at the in-stream site may not be collecting the entire sediment load. The ISCO may not be sucking all the sediment up the tubing or the collection siphon may not be in the thalwag of the stream. The bedload is undoubted not accounted for by the in-stream monitoring.

Comparison of Scotts Level Pollutant Loads with the Chesapeake Bay Watershed Model Computed Loads

To aid in understanding the field-collected data, pollutant loads were calculated using a Chesapeake Bay model which incorporates loading rates for urban pervious, urban impervious, crop, pasture, and forested land use. The model also considers load reductions due to stormwater management measures. Table 8-16 shows the loading rates and acreages for each land use and the results of the computations for nitrogen, phosphorus, and sediment. These results are

compared to the estimated watershed load for Scotts Level Branch. As can be seen from Table 8-16, the CBP Watershed Model overestimates nitrogen by a moderate amount and sediment by a large amount, while phosphorus is under estimated in comparison to the data collected in Scotts Level Branch. The differences between the loads becomes greater if the comparison is made between the CBP Watershed model and the loads based on the monitoring data from the in-stream site SL-01.

Table 8-16 – Land Use and CBP Watershed Model 5.3 Loading Rates for SL-01 Gage Drainage Area and Calculated Loads

Land Use	Acres	Loading Rate N (lbs/ac/yr)	N Load (lbs/yr)	Loading Rate P (lbs/ac/yr)	P Load (lbs/yr)	Loading Rate TSS (lbs/ac/yr)	Sed Load (lbs/yr)
Urban Pervious	1,360.5	10.98	14,938	0.30	408	255	346,928
Urban Impervious	526.0	12.37	6,506	1.33	700	1,985	1,044,110
Crop	0.56	25.73	14	0.82	1	2,820	1,579
Pasture	0.37	8.81	3	0.33	0	376	139
Forest	298.3	3.77	1,125	0.07	21	190	56,677
Total Load	**2,185.7**		**22,586**		**1130**		**1,449,433**
Scotts Level Estimated Load			**17,551**		**1,994**		**480,183**

Summary

This analysis has begun to show patterns of nutrient and sediment loading to Scotts Level Branch. Continued water quality and stream bank soil sampling, along with estimates of loads from the outfall, should provide more refined estimates of the relative contribution of each of these components to the pollutant loads within the watershed, as well as estimates of export from the watershed. These data will allow EPS to more accurately determine the contribution of the various flow components to overall pollutant load estimates, and will form the basis for more accurate determination of benefits from future stream restoration.

8.4 Windlass Run Monitoring – Stormwater Management Assessment

Baltimore County's National Pollutant Discharge Elimination System (NPDES) permit requires the monitoring of a subwatershed for geomorphological impacts resulting from development under the revised Stormwater Management Design Manual (year 2000). In order to comply with this component of the permit, Baltimore County conducted a comprehensive review of the available land for development. An analysis using geographic information systems (GIS) was used for selection of the monitoring subwatershed. The characteristics for determination of the selected subwatershed were:

- 1) an area of open undeveloped land, and
- 2) an area with a zoning category that would lead to development.

Nearly all new development and redevelopment will be affected by the guidelines in the new stormwater design manual, but the denser developments are expected to show a more dramatic change to the stream system. Therefore the study area must have a zoning category of sufficient density to affect the stability of the stream system. The results of a countywide screening,

followed by field verification led to the selection of Windlass Run as the monitoring subwatershed.

The Windlass Run subwatershed is 1,926 acres, and has the potential for a large amount of future development. The level of imperviousness in the subwatershed at the beginning of the study was about 3 % and is expected to increase to well over 20%. Much of the undeveloped land is zoned for manufacturing. The development in this subwatershed began after the extension of MD route 43 was completed. This roadway is the primary access to these new properties and is needed for the intense level of development expected in this subwatershed. If this high-density development is not controlled, it is expected to have a severe impact on the water quality and stability of Windlass Run. The protection provided by the new stormwater management regulations should be easily visible through monitoring of the stream conditions.

Windlass Run is a Coastal Plain stream system typified by a stable, low gradient, sinuous, unconfined, silt and sand channel within well-developed floodplains. Average Rosgen bankfull width and corresponding bankfull depths are 10 and 2 feet, respectively. The Windlass Run system is very stable, and there are no areas of moderate or severe streambank erosion. One year of stream gage data was recorded by U.S.G.S. in 1992 – 1993. Well-vegetated stream buffers surround the stream. The upper portion exhibits multiple channels, which are stable and meander through non-tidal wetlands. These conditions are reflective of those described in the Bird River watershed plan that was completed in 1995.

Monitoring in the Windlass Run watershed includes stream geomorphology and biology. The Baltimore County NPDES Municipal Stormwater Discharge Permit only requires the stream stability geomorphological monitoring.

8.4.1 Stream Geomorphologic Monitoring

Six (6) monitoring sites in the Windlass Run subwatershed are shown in Figure 8-10 below. The site selection process took into consideration the location of future development and the extension of MD Route 43. Three sites are located along the mainstem: two above (WR3, WR5) and one below (WR2) the crossing of the proposed MD Route 43 extension. One site (WR4) is on a tributary within the area of proposed industrial and high-density development, and down stream of Route 43. Another cross section (WR6) is located on a tributary within the area of proposed development. The last cross section (WR1) is a reference site on a tributary near the bottom of the subwatershed. This tributary is within an area zoned for agricultural uses and should not be affected by the other development activities in the watershed. Sites WR1 and WR6 are not down slope or downstream of any of the Route 43 construction.

The geomorphic monitoring consists of a monumented channel cross-section measurement, a channel slope/ profile measurement, and a Wolman pebble count. Cross sections were selected on the reach between meander bends and where the conditions best represented confined flow. Profiles were also surveyed at all of the cross section reaches and include the cross sections. The procedures outlined by D. Rosgen (1996) were generally used for channel classification and stability assessment. The six cross sections and profiles have been surveyed annually since 2002. Note, however, that no profile was done at Cross Section #6 in 2002 and 2003 due to heavy vegetation. Pebble counts, sinuosity, and a Rosgen Level 3 assessment were also completed at each site. The monitoring will continue yearly.

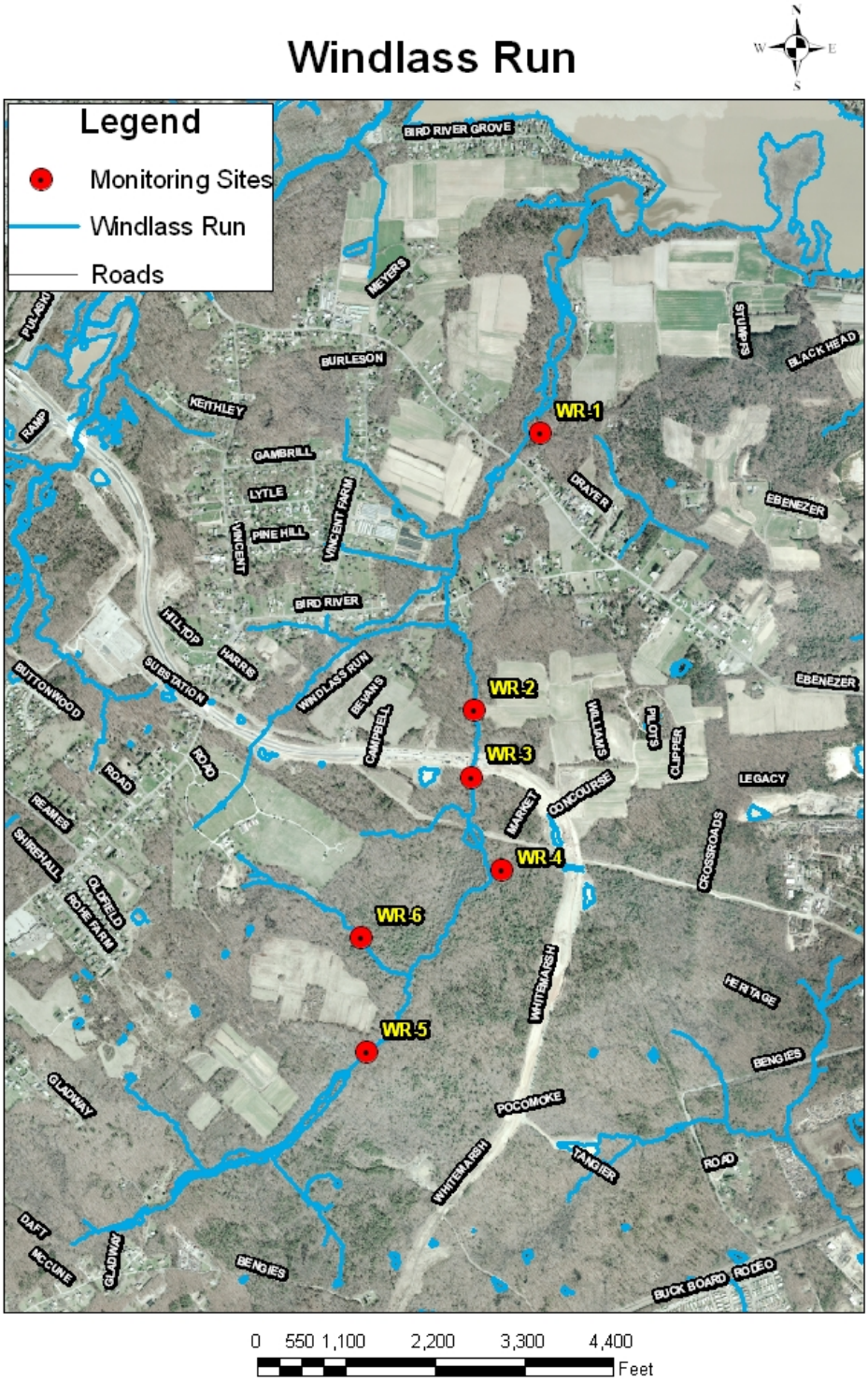


Figure 8-10: Windlass Run Aerial Photograph Showing Monitoring Station Locations.

Figure 8-11 shows the potential for development throughout the watershed. Figures 8-12 through 8-14 show the progression of development in Windlass Run, from 1995-2008, in years

for which orthophotographs were available. Development occurring in the interval between years is summarized below. Changes in geomorphology and biology related to the land disturbance caused by development are discussed in the results for each monitoring component.

1995 – 2002:

- A small housing development was built 2,850 feet northwest of WR-5.
- Two driveways were cleared 1,520 feet west of WR-2.

2002 – 2005:

- The roadbed for the Route 43 extension was cleared.

2005 – 2008:

- The Route 43 extension was paved.
- A roadway was cleared 2,470 feet southwest of WR-5.
- Land clearing and grading for commercial/industrial complexes occurred 1,330 feet east of WR-6, 95 feet east of WR-2, WR-3, and WR-4, and 380 feet west of WR-1.

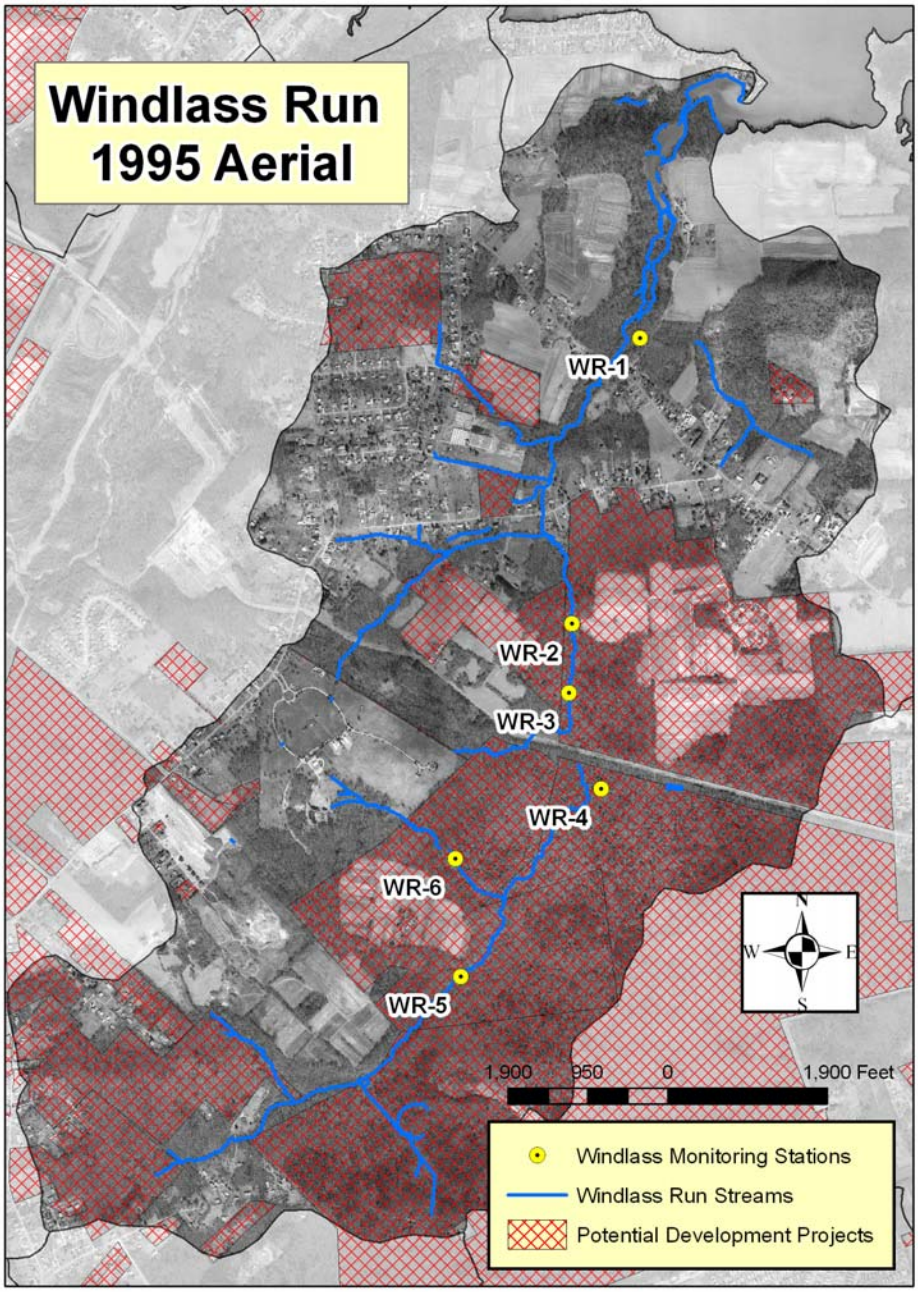


Figure 8-11: Orthophotograph of Windlass Run watershed, 1995, with potential for development highlighted in red cross-hatching.

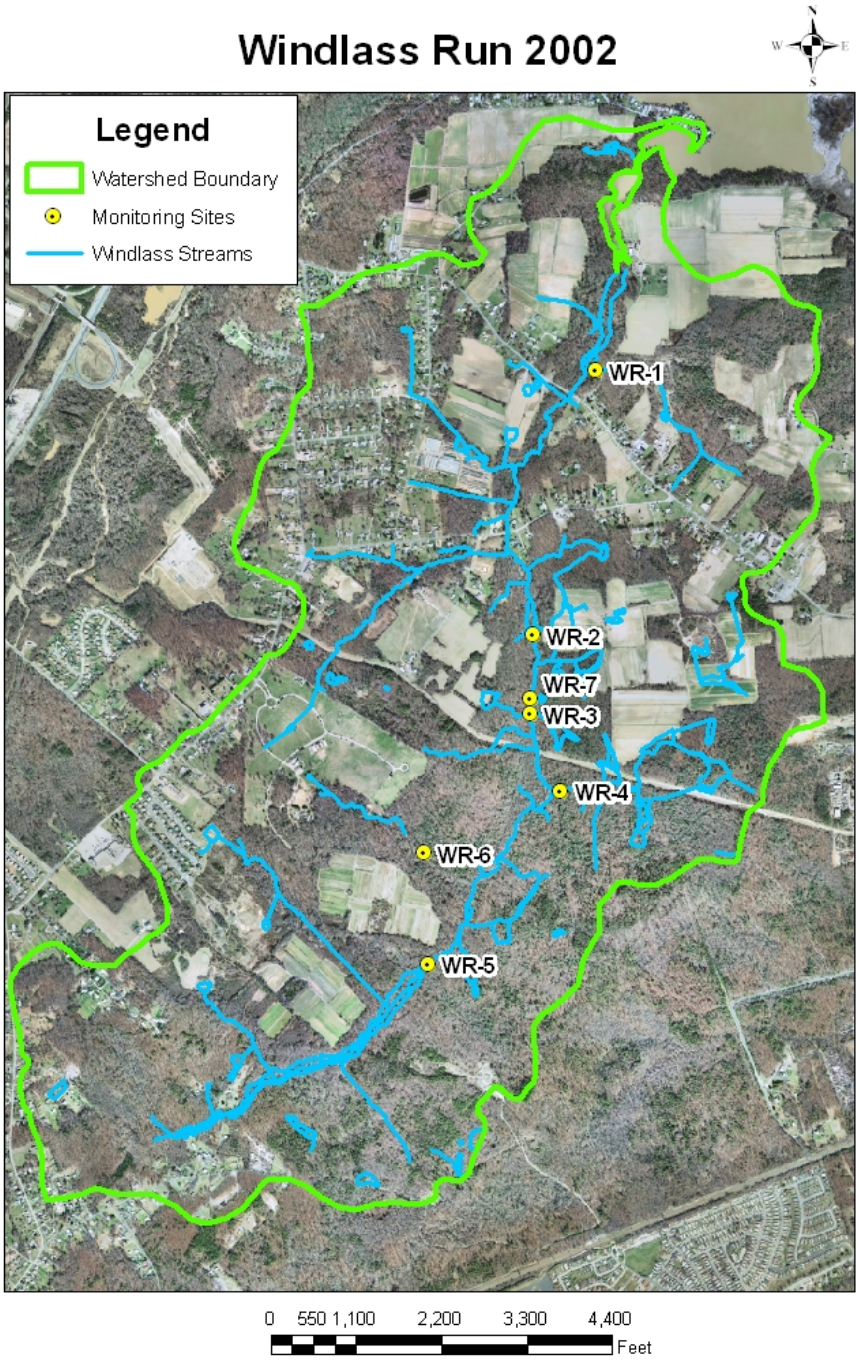


Figure 8-12: Windlass Run watershed orthophotograph, 2002.

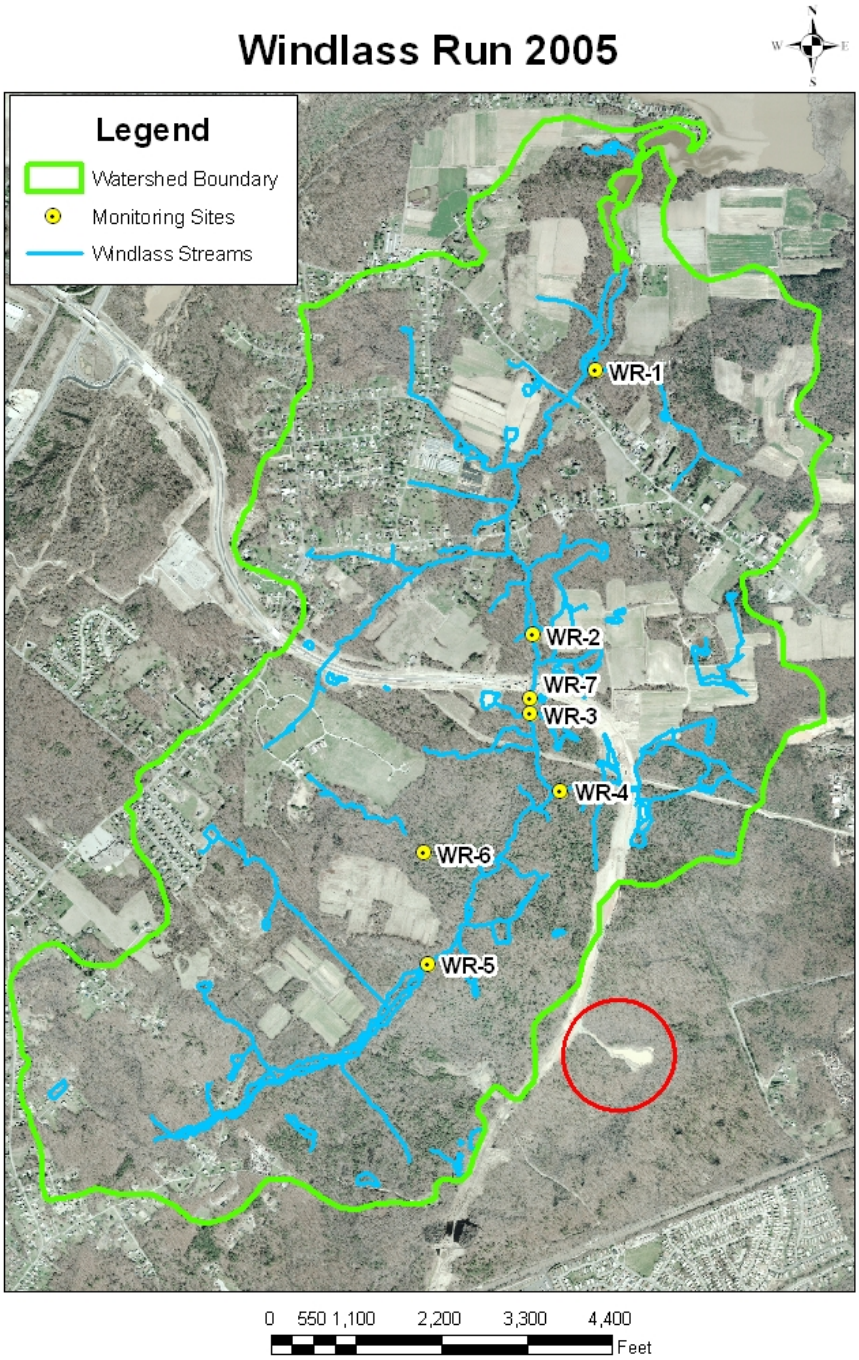


Figure 8-13: Windlass Run orthophotograph, 2005. New development/grading is circled in red.

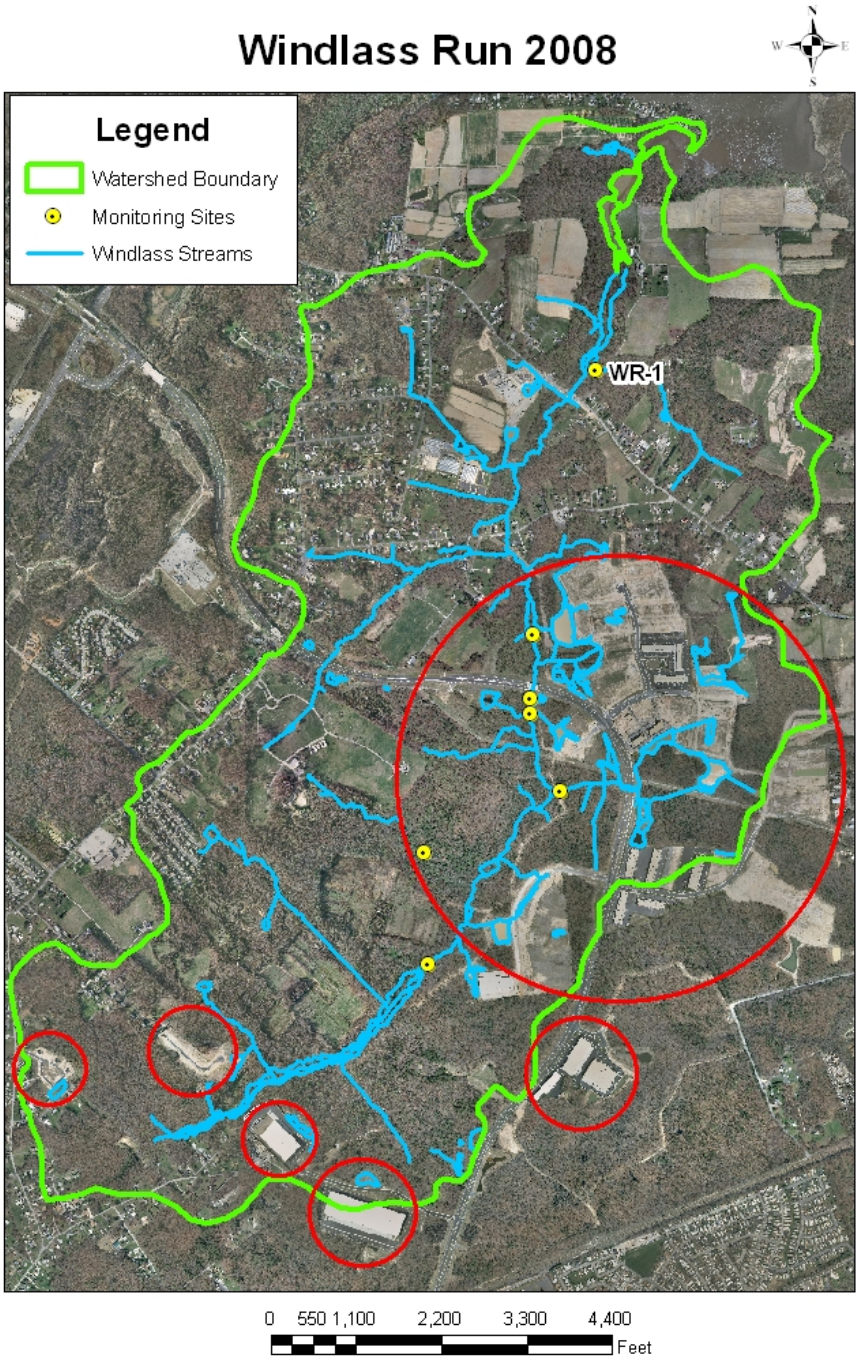


Figure 8-14: Windlass Run orthophotograph, 2008. New development/grading is circled in red.

Windlass Run Monitoring Results:

The cross sections and profiles were overlain to reveal any morphological changes between 2010-2011 and 2002-2011. Pebble count data were summarized using D_{50} or dominant particle size (if the particle size distribution did not allow for determination of D_{50}). The change in the

reaches over the period of record are discussed below and summarized in Figures 8-15 and 8-16. Bank height ratios were calculated to aid in determining the stability of each cross section. They are shown in Figure 8-17.

The amount of material moving through the thalweg of each profile appears to primarily be related to precipitation. Although each stream reach varied in the direction of its response (cut or fill), the reaches were typically most active in the same years. Windlass Run was very active in 2008, after a very dry year in 2007 and above average precipitation in 2008. Particle size distribution showed little relationship to development activities. There was a small increase in D_{50} in 2007, at the onset of development, but the profiles with the greatest change in particle size were the tributaries unaffected by development. Note that the changes in particle size are small. Particles of 0.062 mm are silt/clay, while particles of 0.25 mm are fine sand. Bank height ratios varied annually, but seemed to modulate around the value of 1.0 (indicating stability).

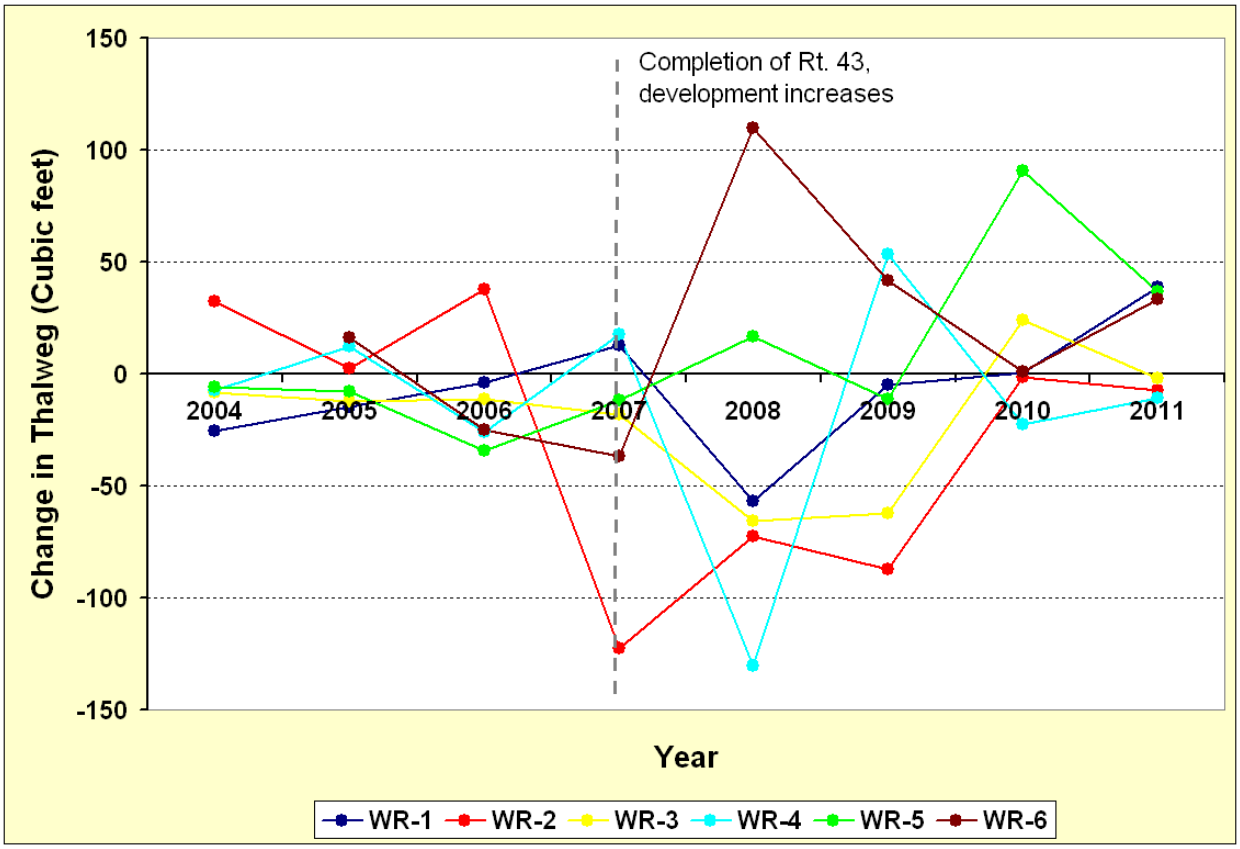


Figure 8-15: Amount of material moved through thalweg in Windlass Run during entire study period

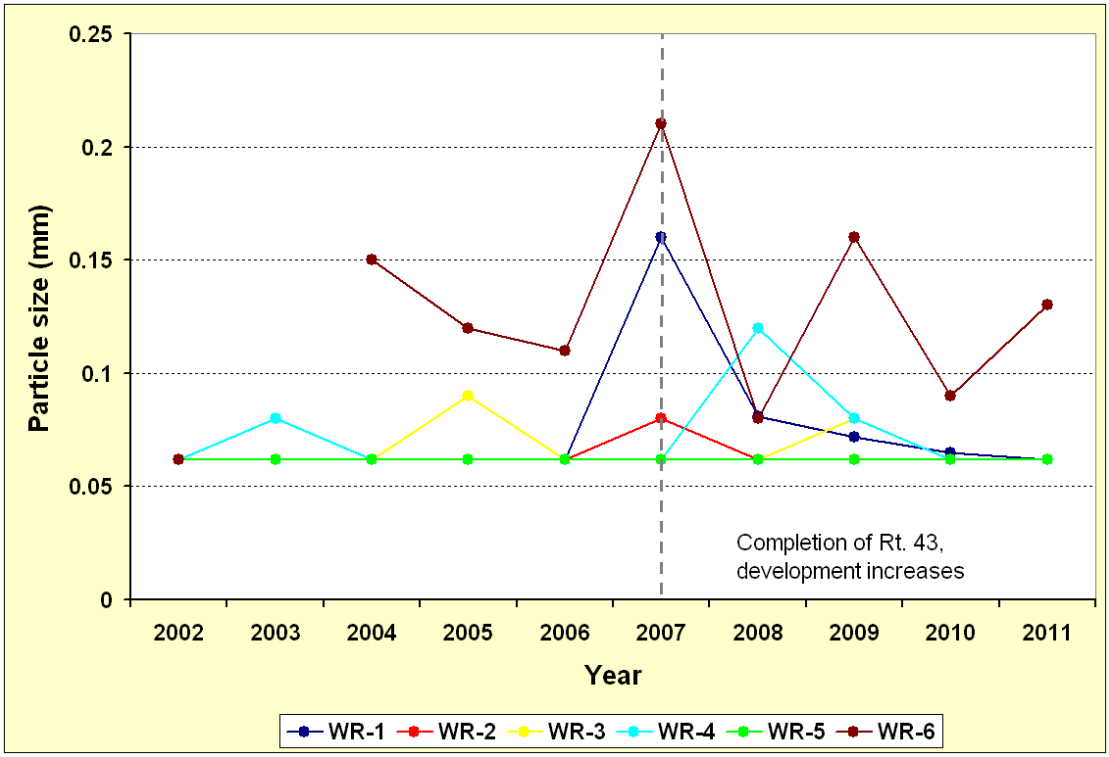


Figure 8-16: Summary of pebble counts in Windlass Run during entire study period. Particle size was determined as D_{50}. If the particle size distribution did not allow for D_{50} determination, the dominant particle size was used.

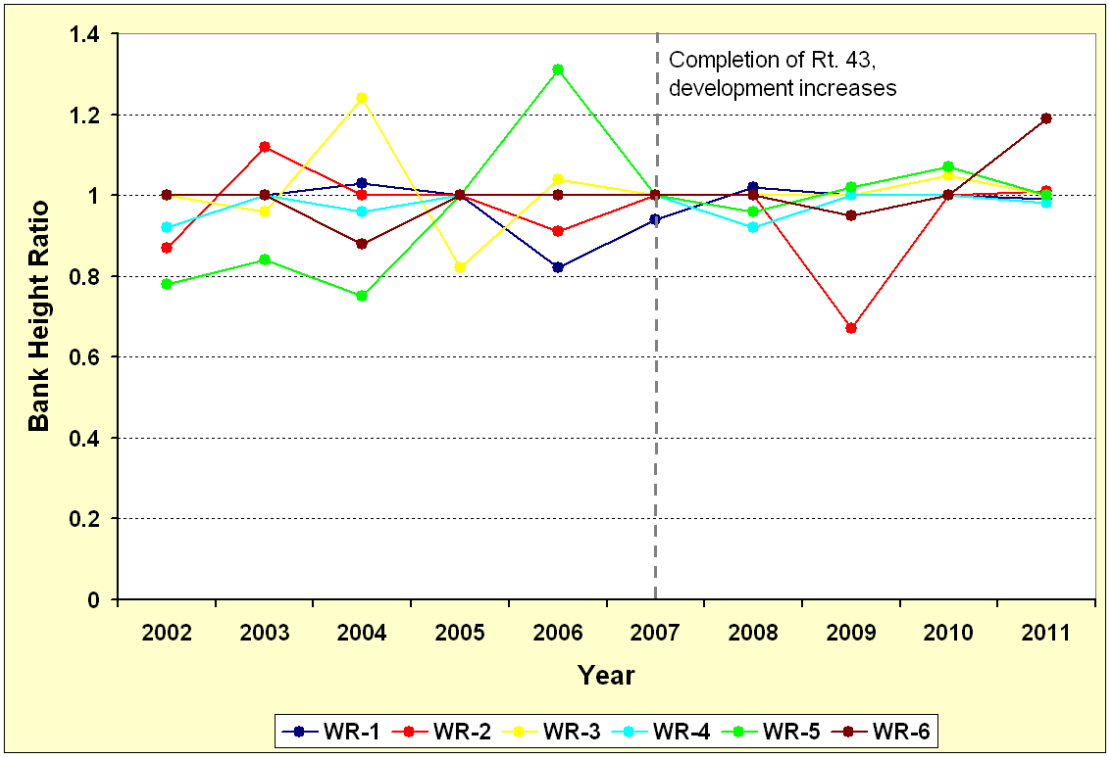


Figure 8-17: Windlass Run Bank Height Ratios

The Windlass Run stream channels are low gradient and well connected with their flood plains at bankfull flows. They also have good riparian vegetation coverage along their banks. The stream system is almost entirely within a well-forested setting providing good habitat, erosional resistance, and canopy coverage. Although some changes in channel morphology have been observed annually, Windlass Run remains in good condition.

8.4.2 Biological Monitoring

Benthic macroinvertebrates are being used as indicator organisms to monitor the effects of disturbance in the Windlass Run watershed. The condition of the benthic macroinvertebrate community before and after development will help determine the effectiveness of the new stormwater regulations at maintaining the suitability of Windlass Run for aquatic life.

Benthic macroinvertebrate sampling was conducted as per MBSS protocols. Benthic macroinvertebrates were sampled annually, during the spring index period (March 1st - April 30th), at WR-1, WR-2, WR-3, WR-4, and WR-5. WR-1 was not sampled in 2004 and 2006 because a beaver dam downstream of the station, on the Windlass Run mainstem, was causing backwater effects within the station reach. Data for WR-1 from 2005 are missing because the sorted sample had dried before it could be identified. A Benthic Index of Biotic Integrity (BIBI) was calculated using metrics developed by MBSS for Coastal Plain streams. The BIBI scoring criteria are: 1.00-1.99 (Very Poor), 2.00-2.99 (Poor), 3.00-3.99 (Fair), and 4.00-5.00 (Good). Physical habitat assessments performed during benthic sampling were converted to a physical habitat index (PHI) developed by MBSS. The PHI scoring criteria are: 81-100 (minimally degraded), 66-80 (partially degraded), 51-65 (degraded), and 50 or less (severely degraded).

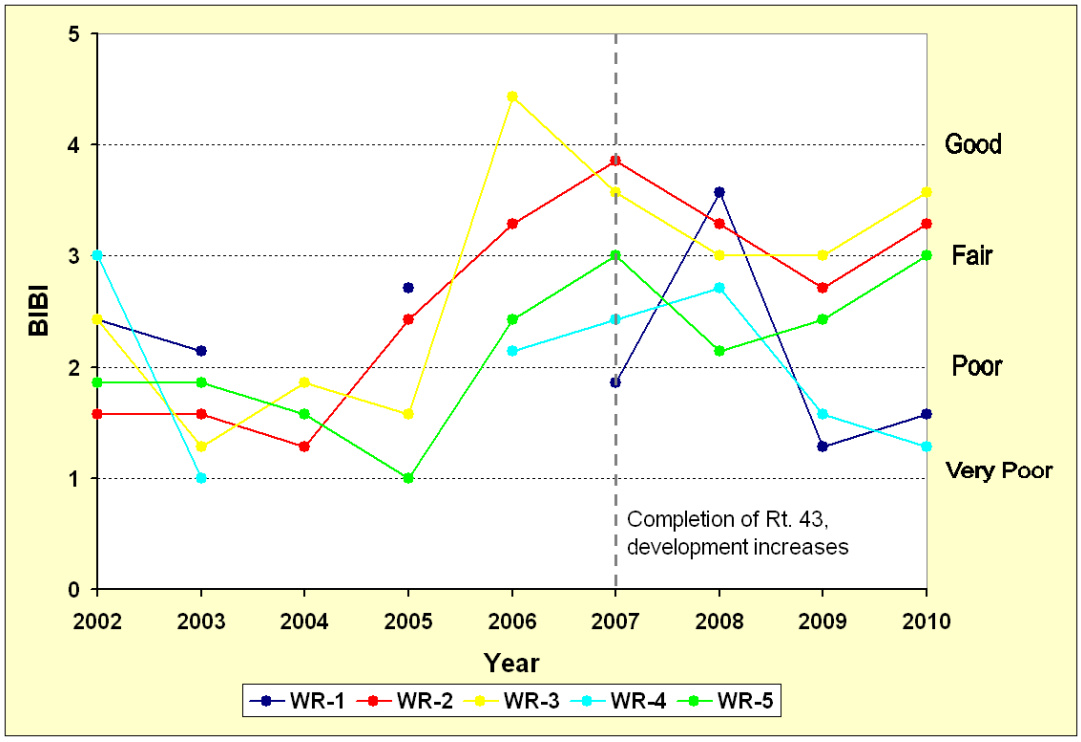


Figure 8-18: Windlass Run BIBI Scores

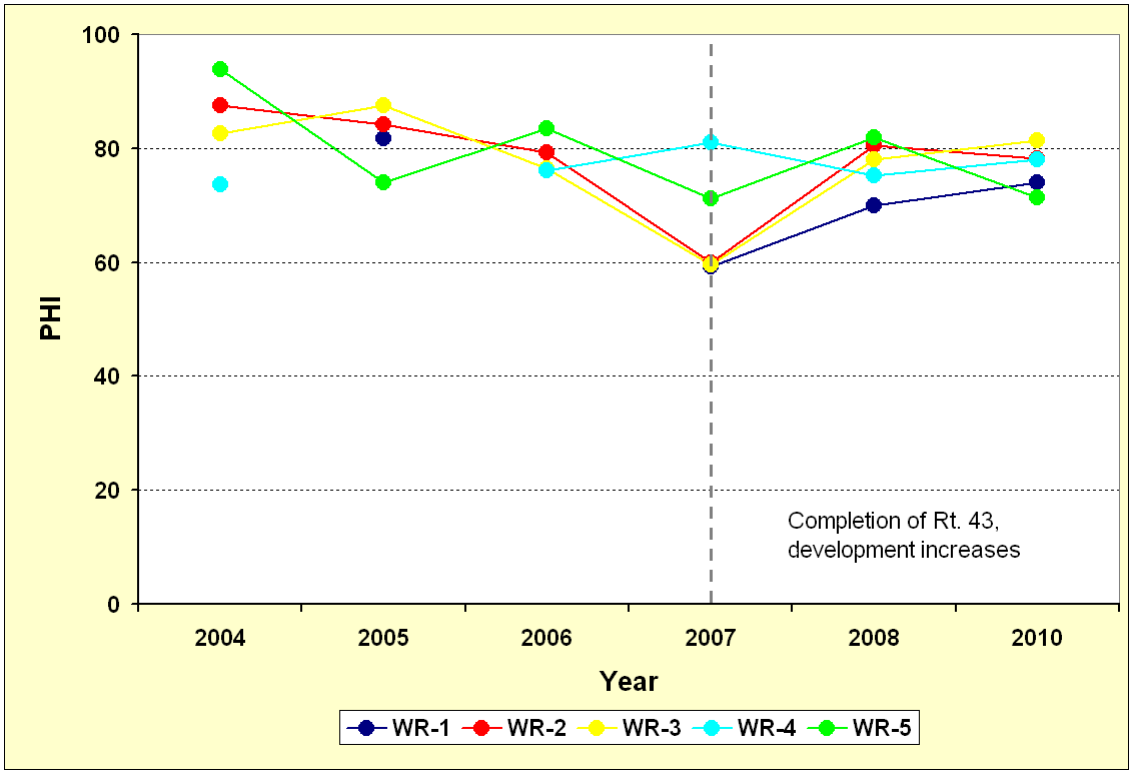
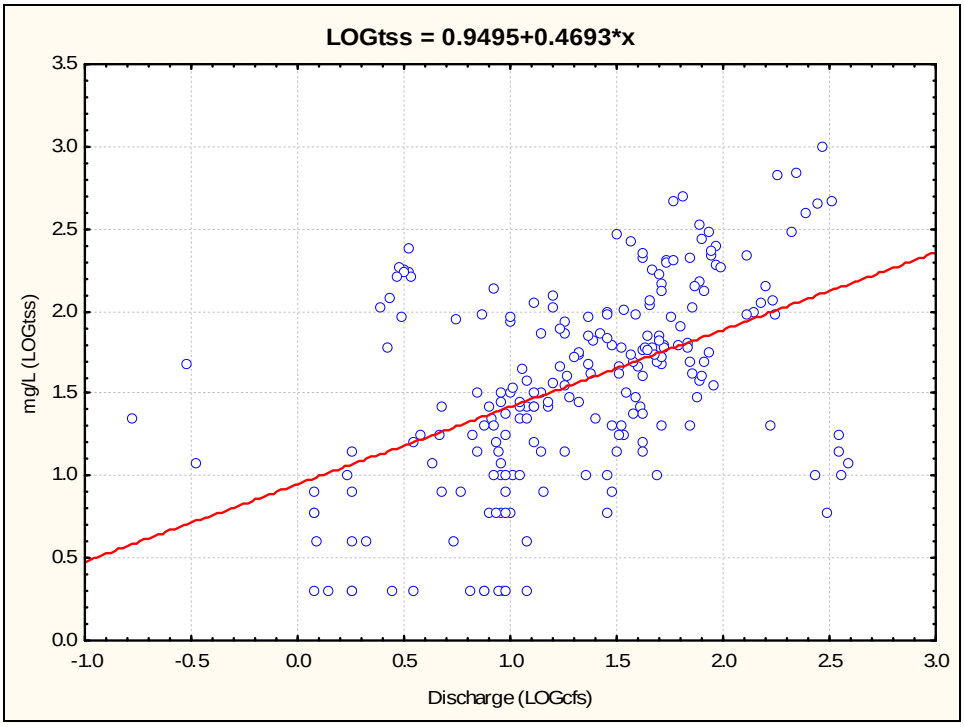


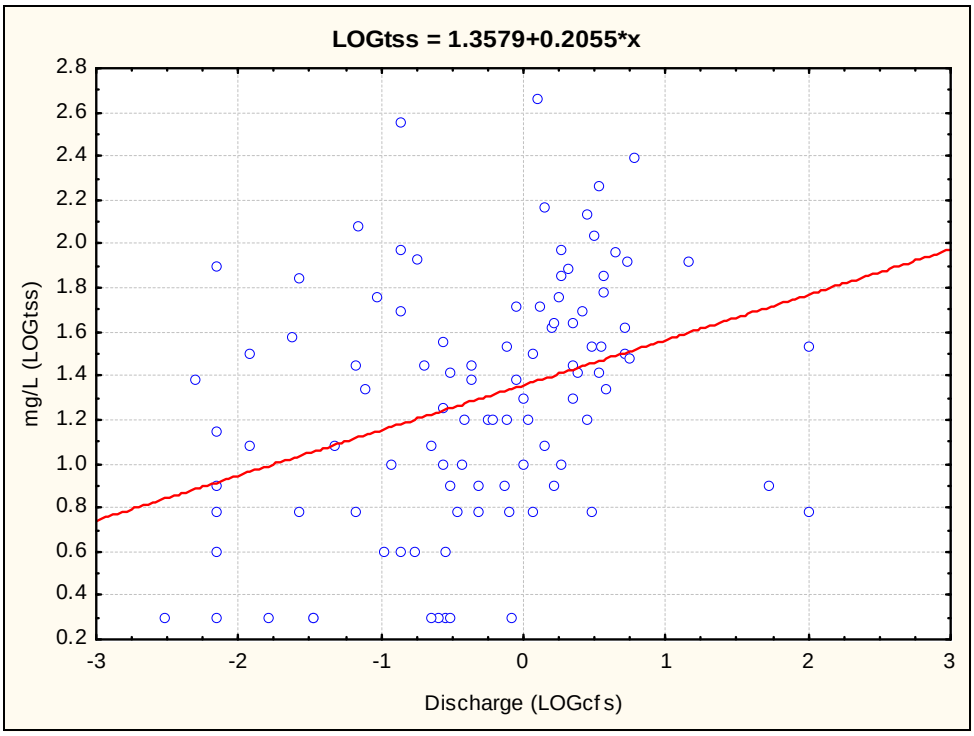
Figure 8-19: Windlass Run PHI Scores

The biological data show little evidence of the influence of development. Index values appear to fluctuating in response to climactic conditions. During dry years, less habitat is available for macroinvertebrate populations, so that some decrease in biological index values occur the following year. During wet years, habitat availability and quality increase, with corresponding increases in index values. Although biological index values peaked in 2007, at the beginning of major earth-moving, the indices increased again between 2009-2010. Physical habitat index values have declined very slowly over the period of record, although all remain at minimally or partially degraded values. If development had been responsible for the decrease in habitat quality, a clear change would be expected around 2007. The effects of a long history of agricultural land use will need to be identified before the effects of recent development are fully understood. Further monitoring will help determine the effectiveness of storm-water management techniques applied in Windlass Run.

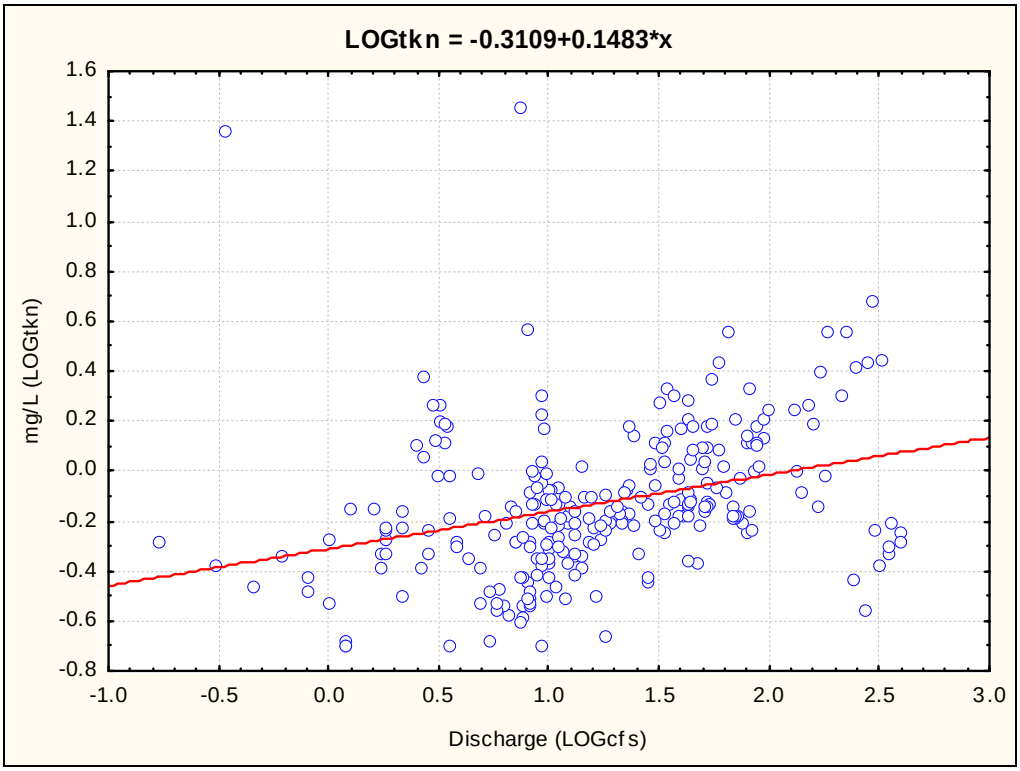
Appendix 8-1: Regression Analysis Graphs



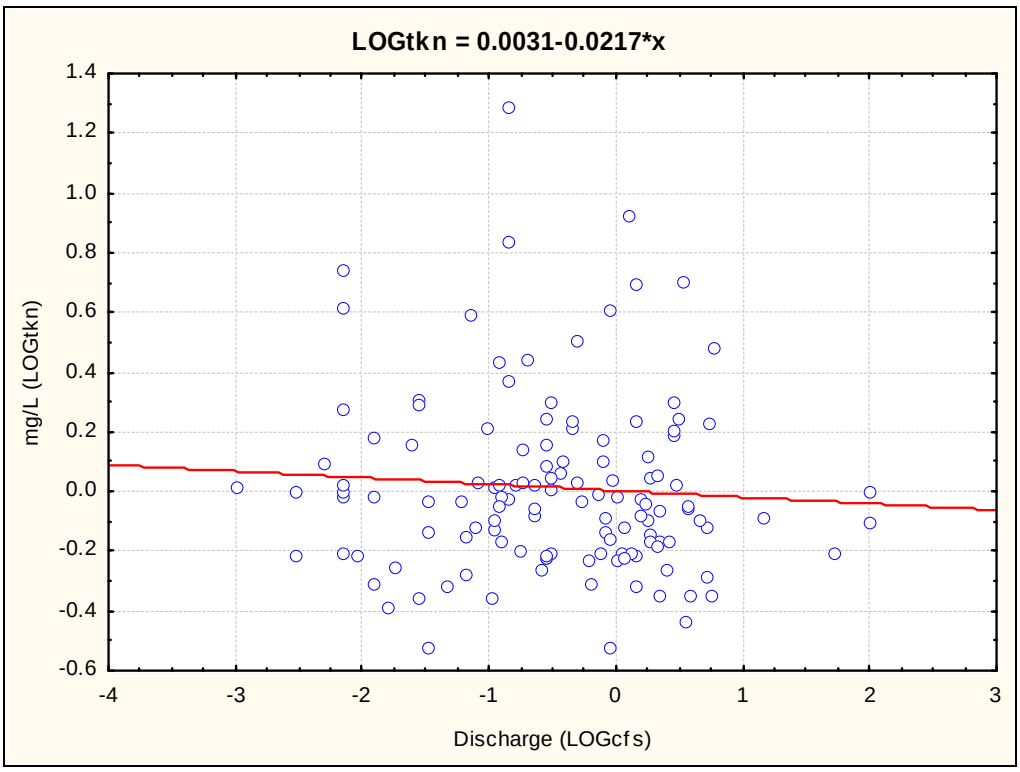
SL-01 Total Suspended Solids (TSS) Data and Regressions for 2005-2010.



SL-09 Total Suspended Solids (TSS) Data and Regressions for 2005-2010.



SL-01 Total Kjeldahl Nitrogen (TKN) Data and Regressions for 2005-2010.



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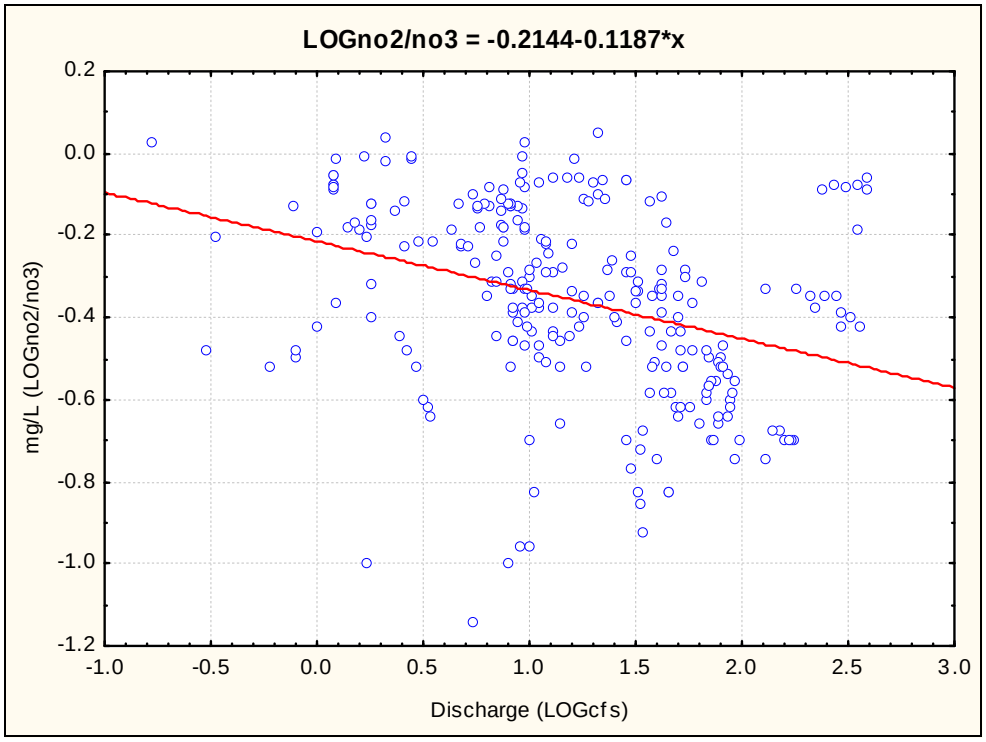
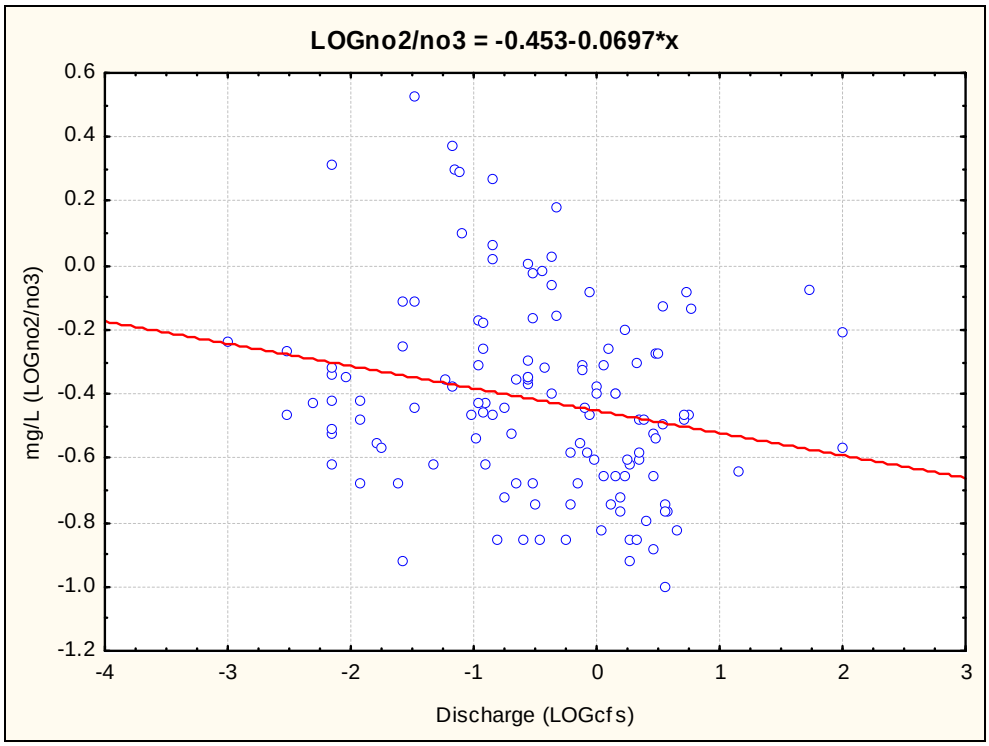


SL-01 Nitrate/Nitrite (NO_2/NO_3) Data and Regressions for 2005-2010.



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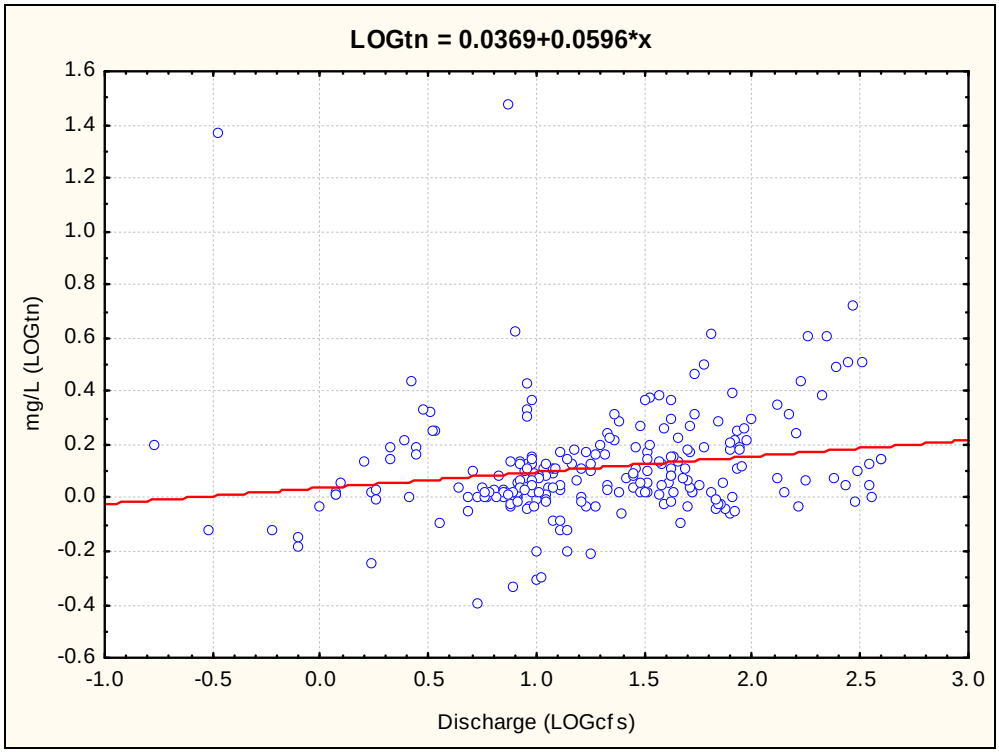
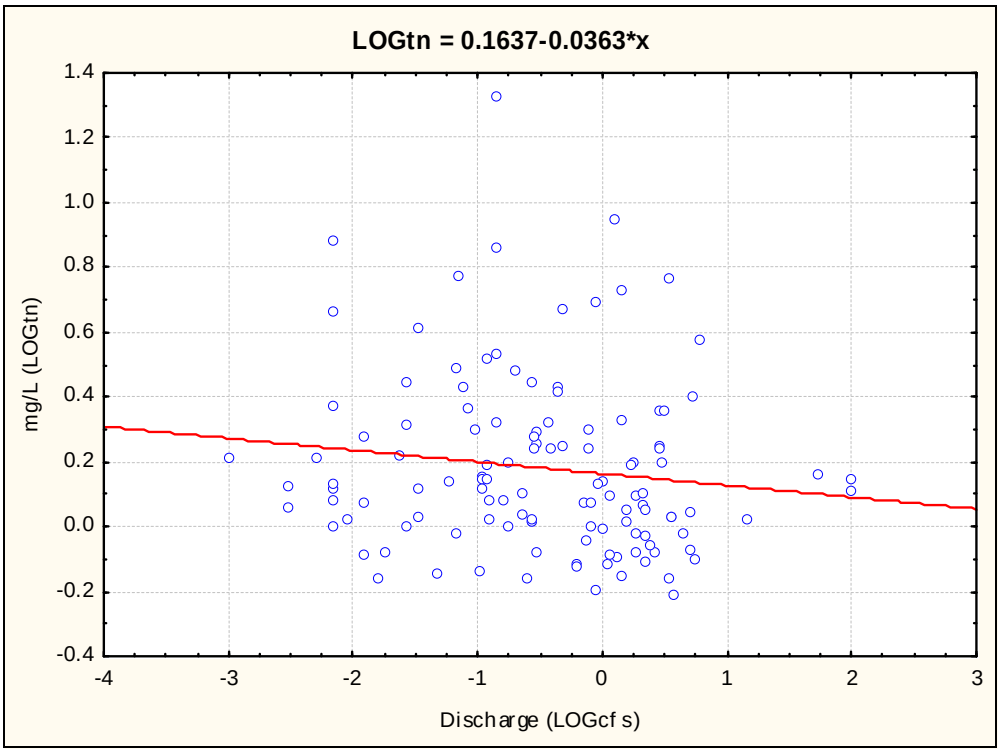


SL-01 Total Nitrogen (TN) Data and Regressions for 2005-2010.



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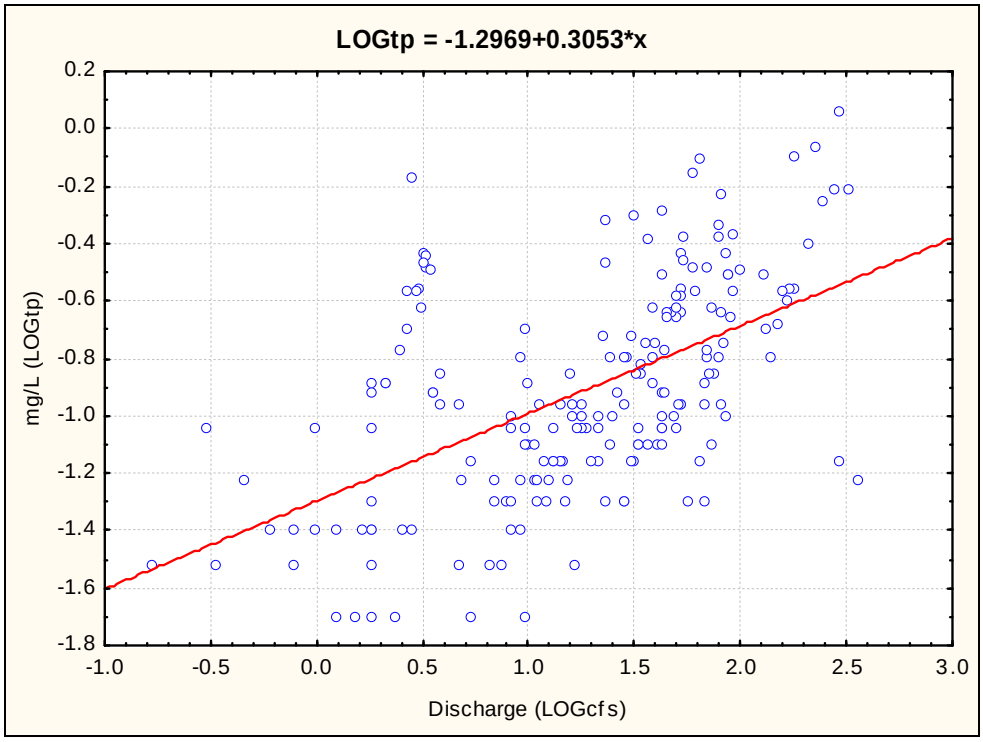
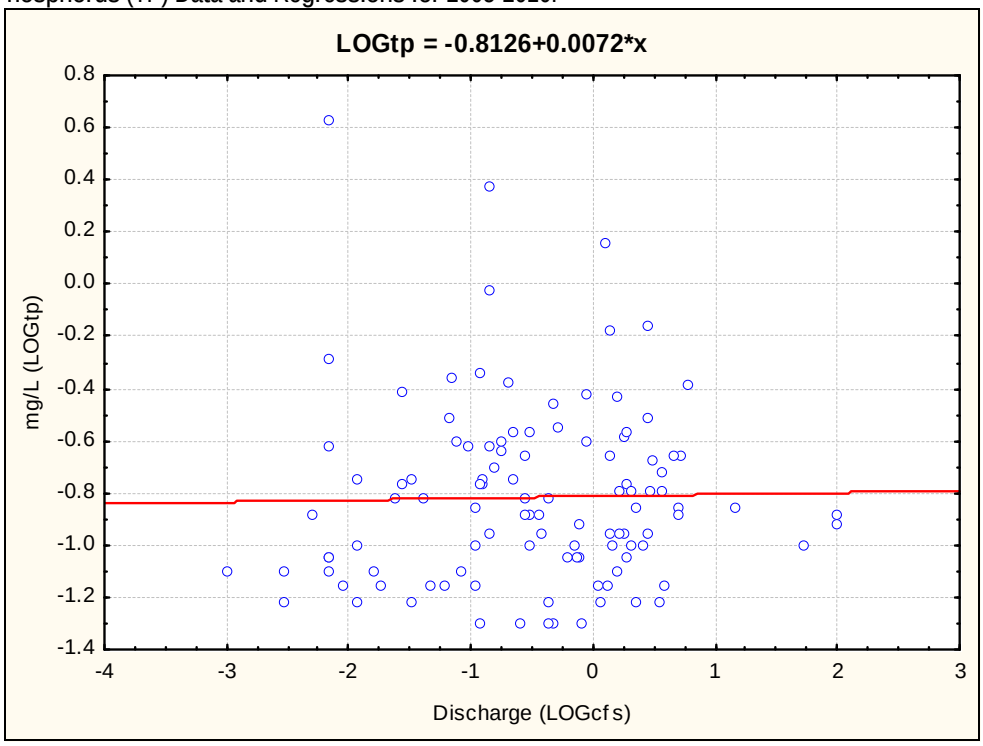


SL-01 Total Phosphorus (TP) Data and Regressions for 2005-2010.



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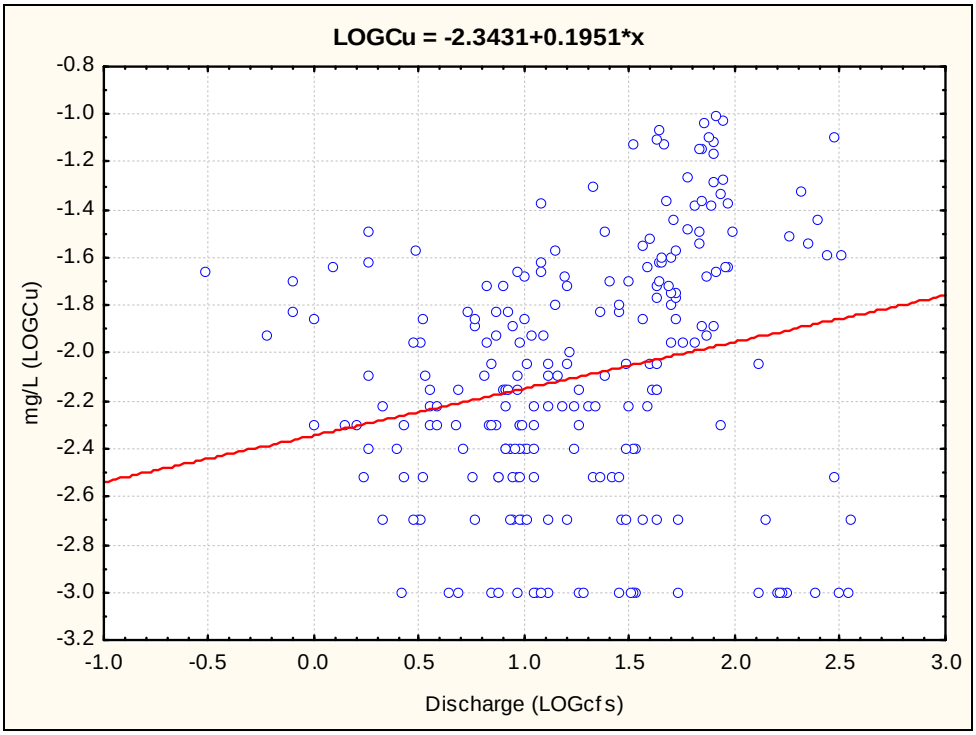
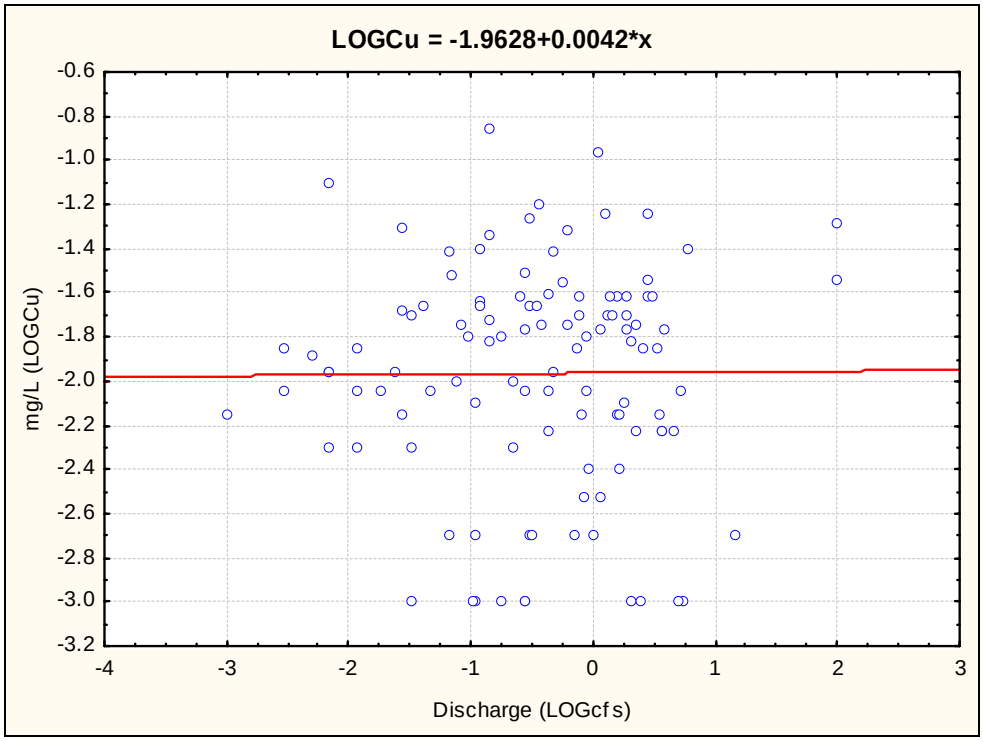
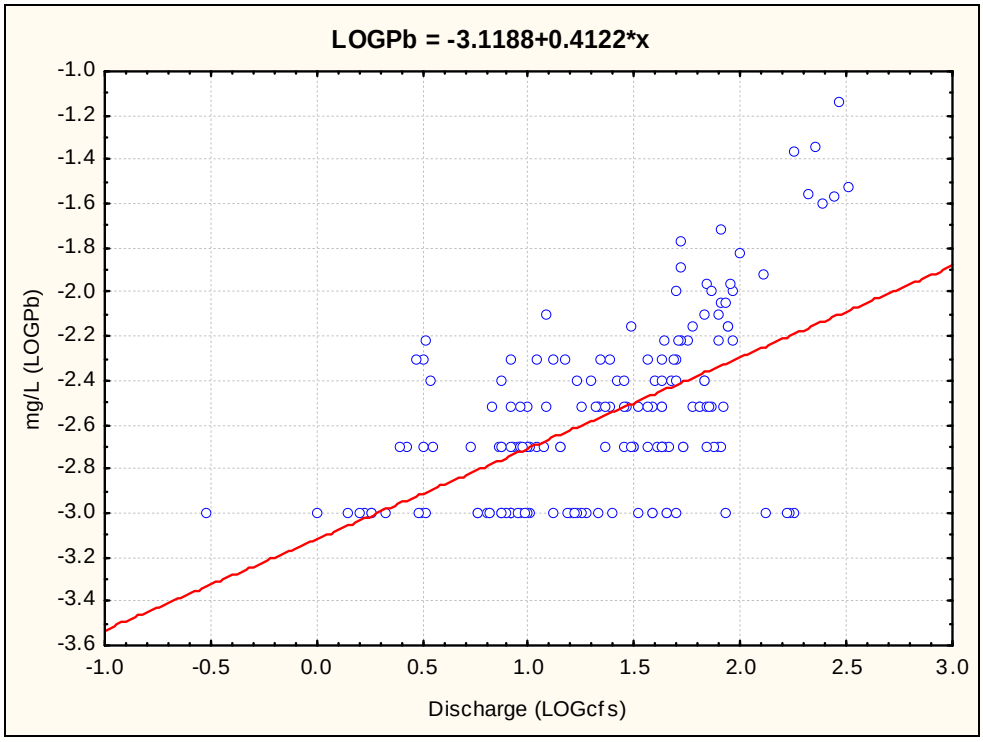


SL-01 Total Copper (Cu) Data and Regressions for 2005-2010.



SL-09 Total Copper (Cu) Data and Regressions for 2005-2010.



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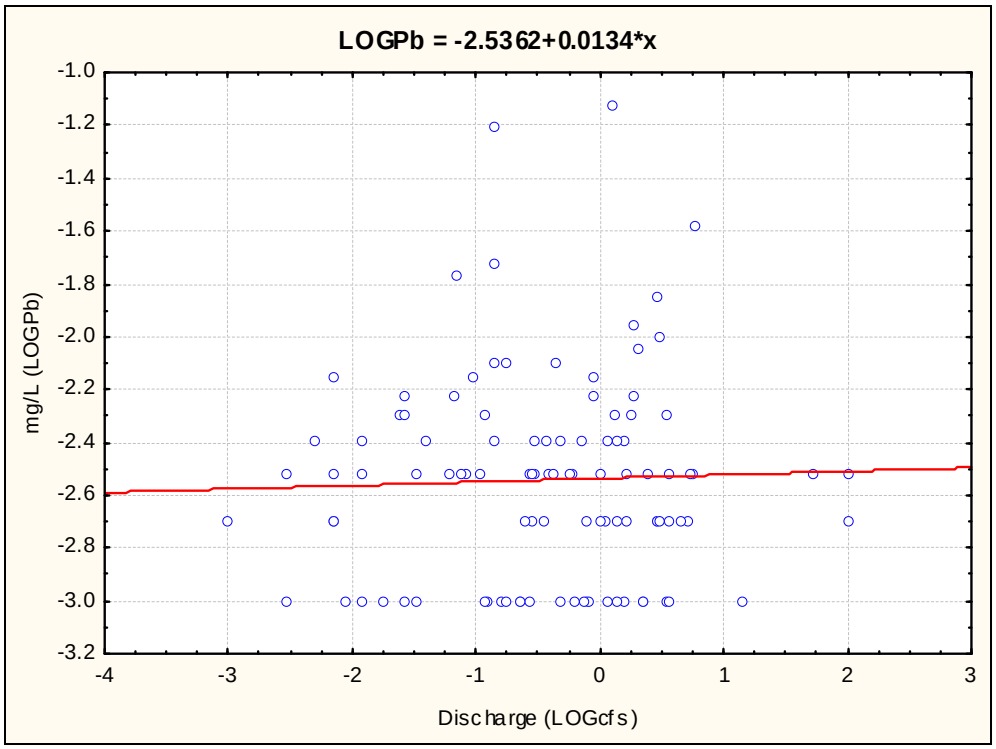

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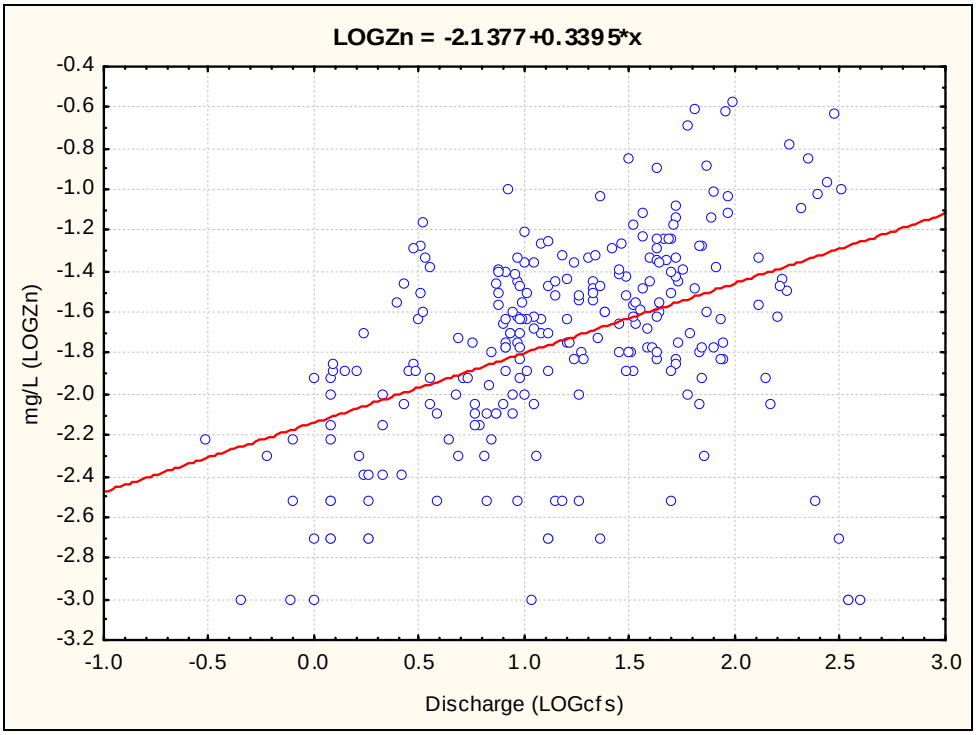

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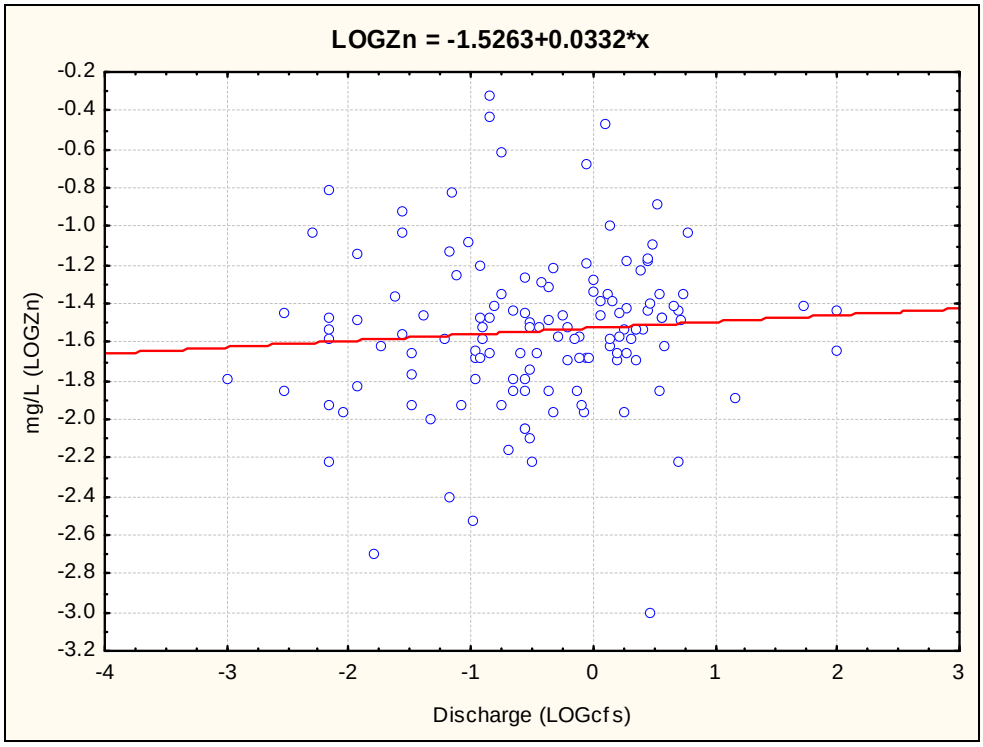

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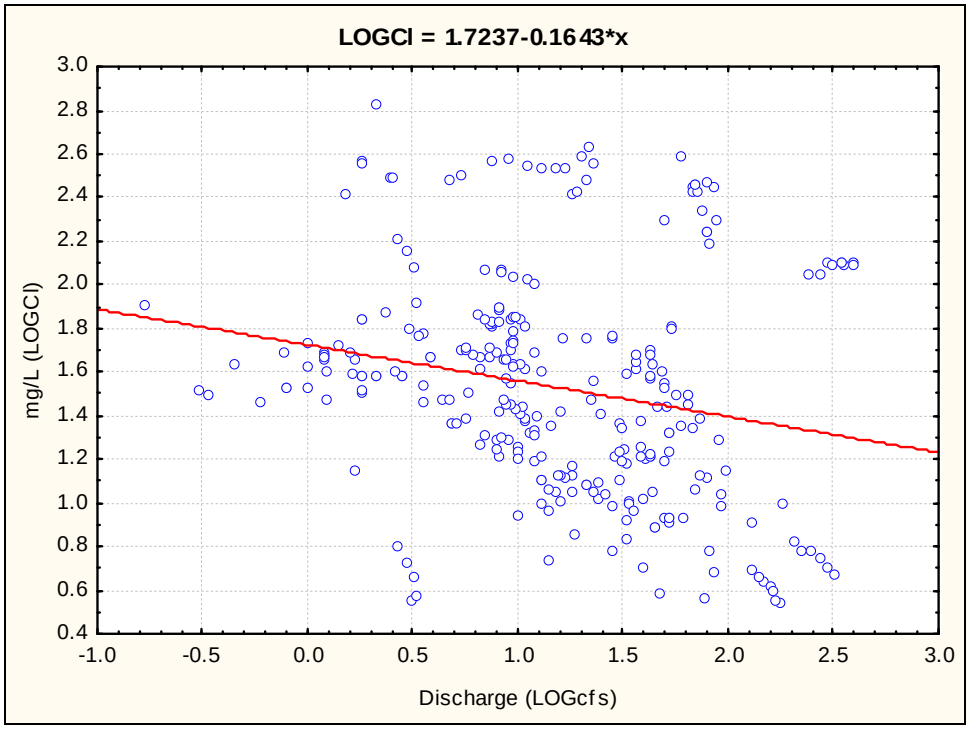
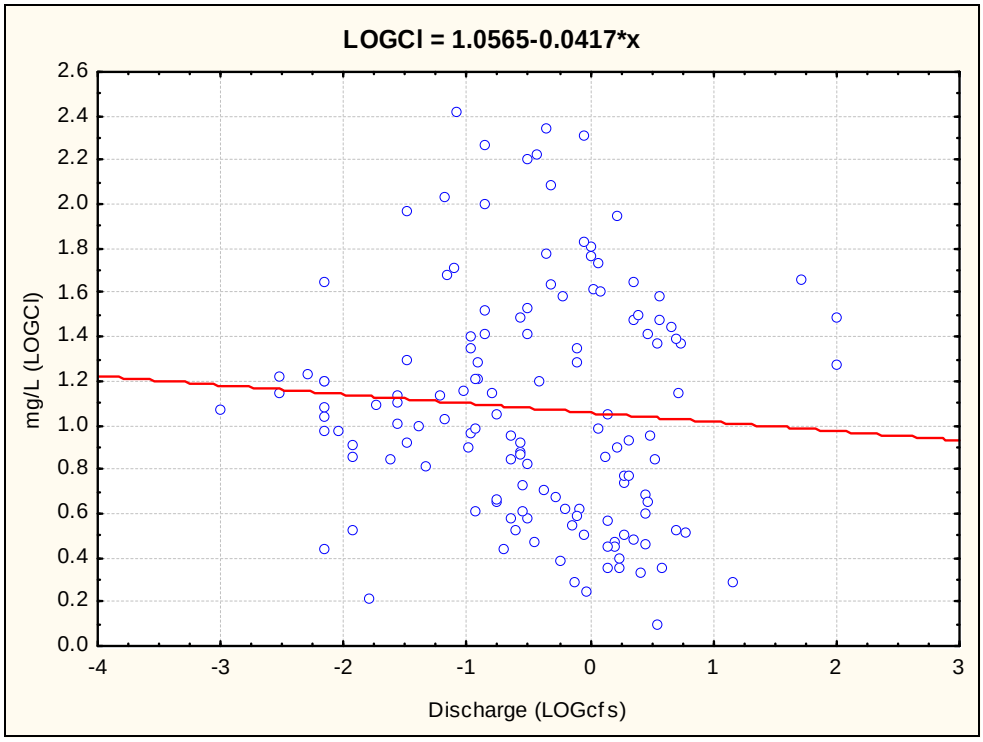


SL-01 Chloride (Cl) Data and Regressions for 2005-2010.



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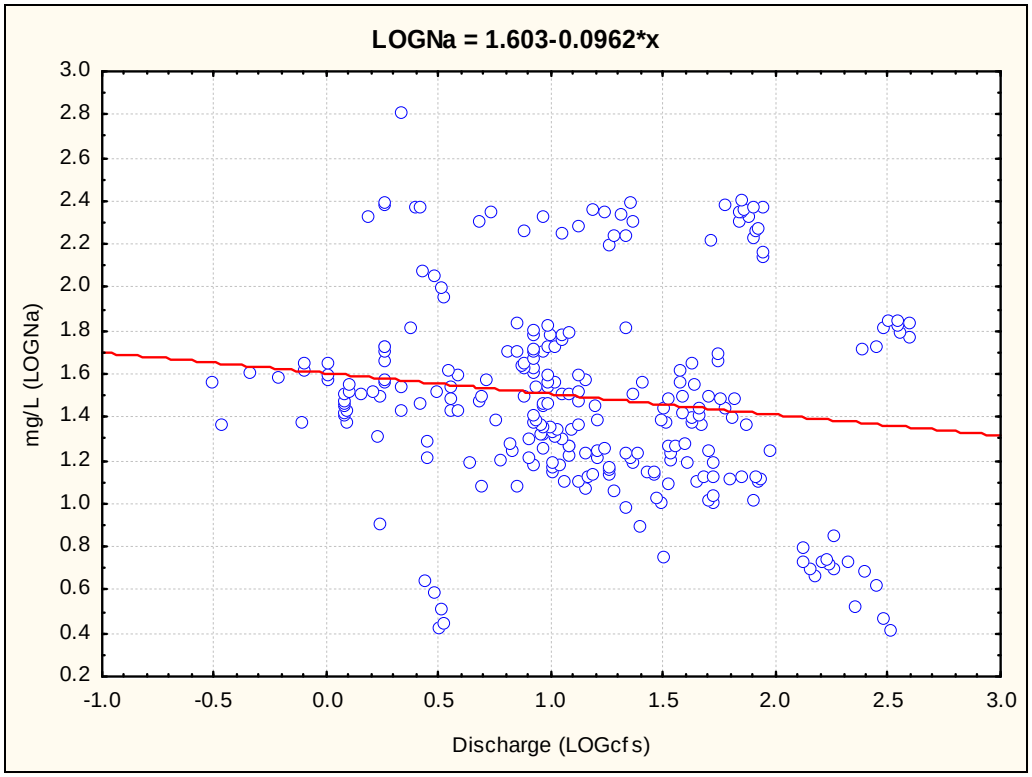
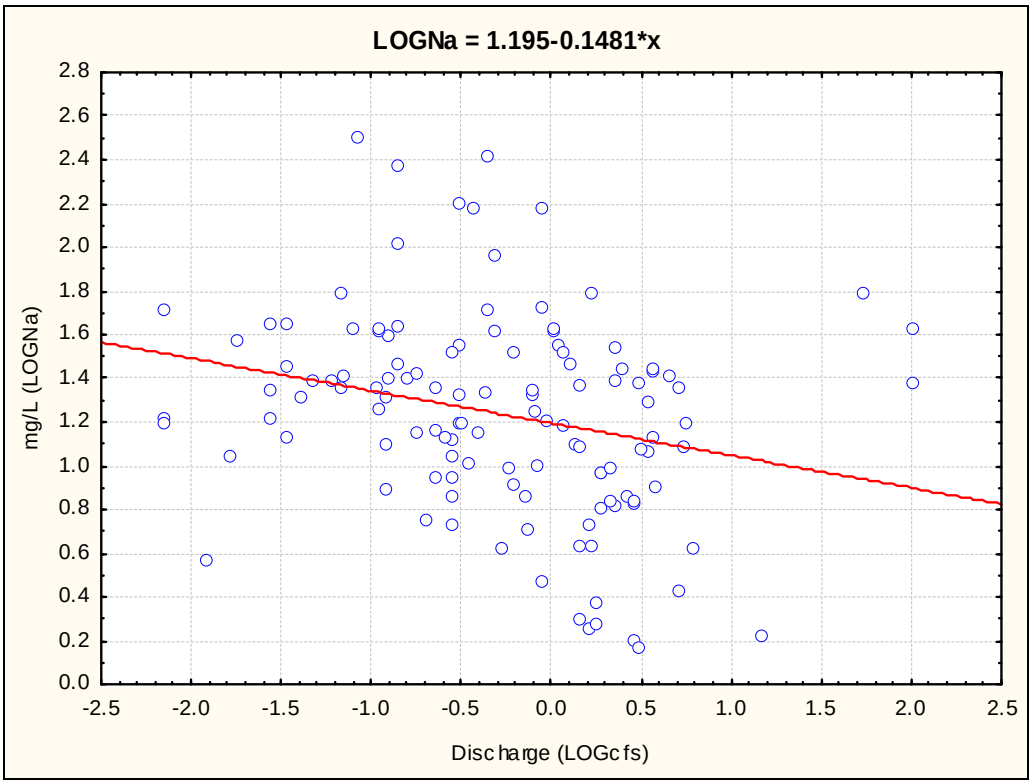
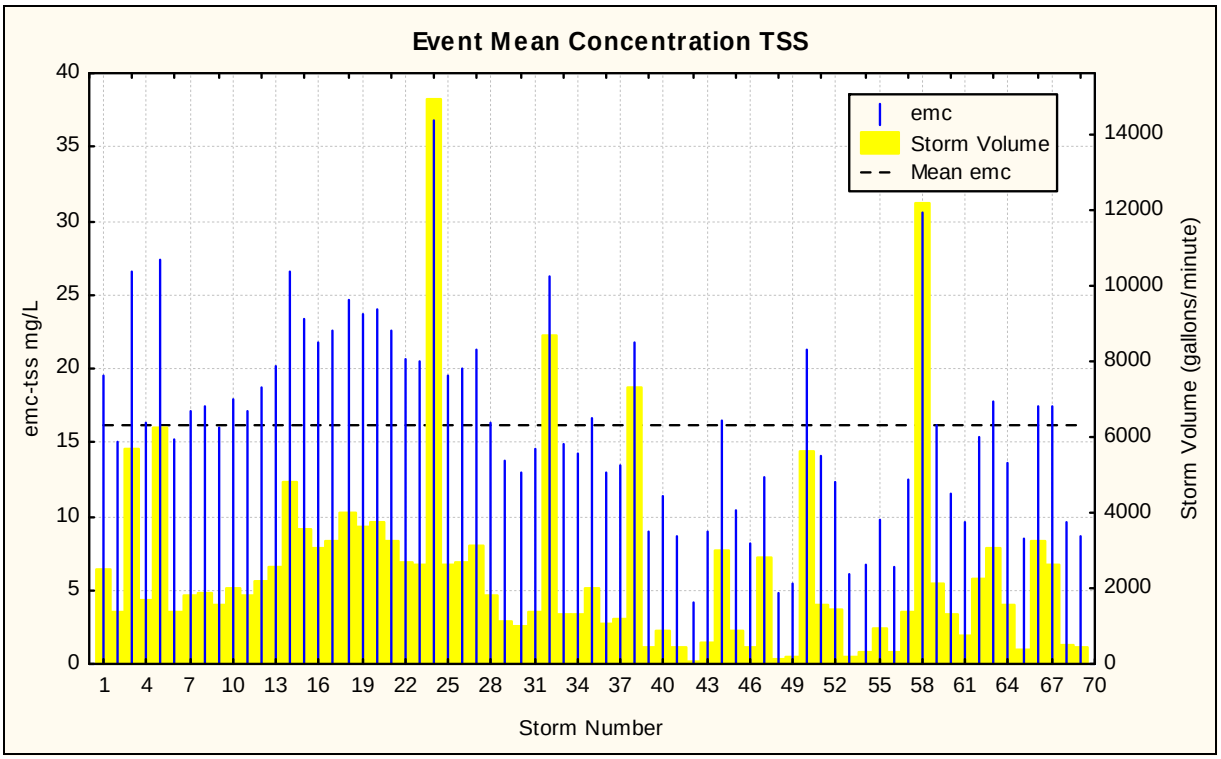


SL-01 Sodium (Na) Data and Regressions for 2005-2010.

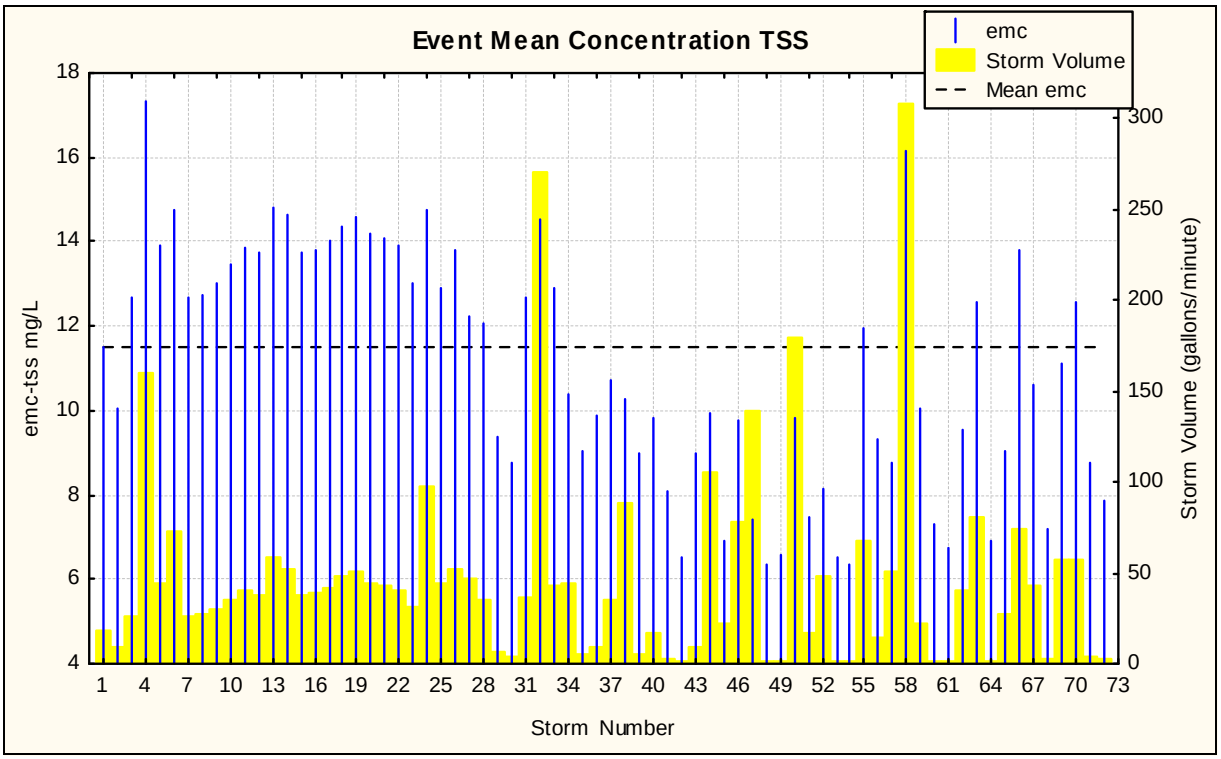


SL-09 Sodium (Na) Data and Regressions for 2005-2010.

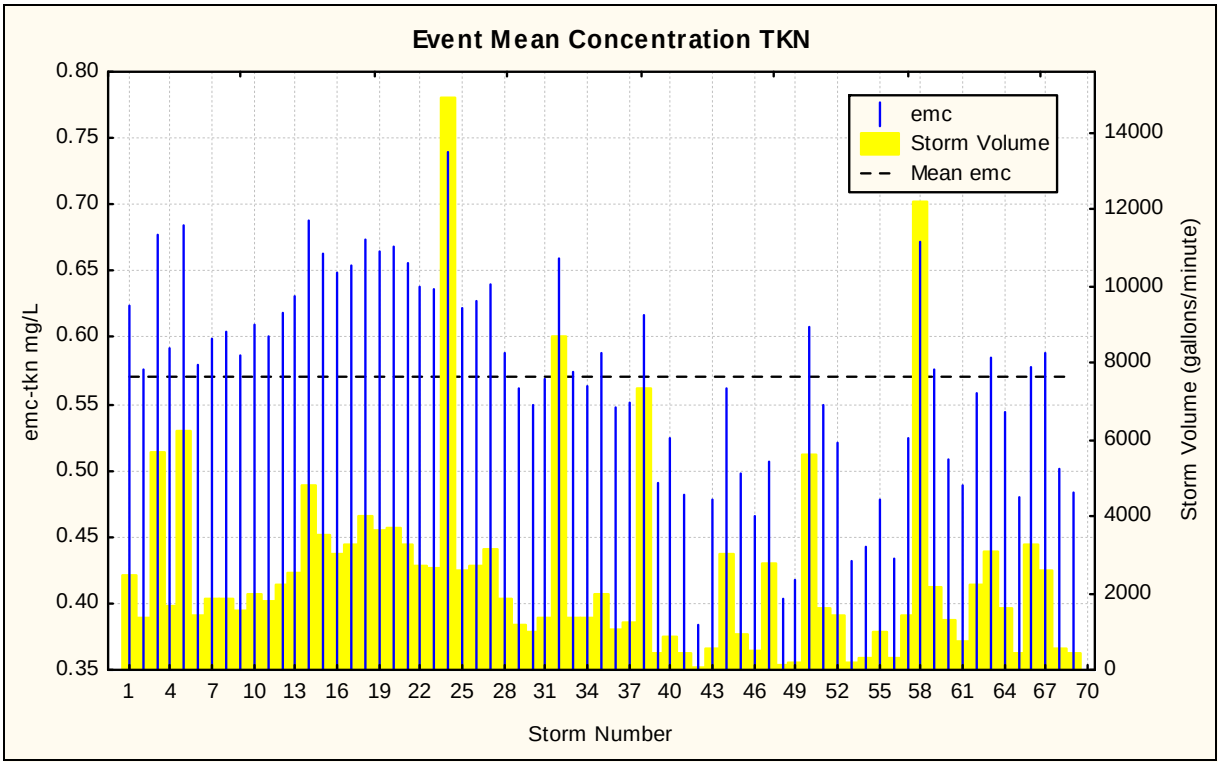
Appendix 8-2: Event Mean Concentration Graphs



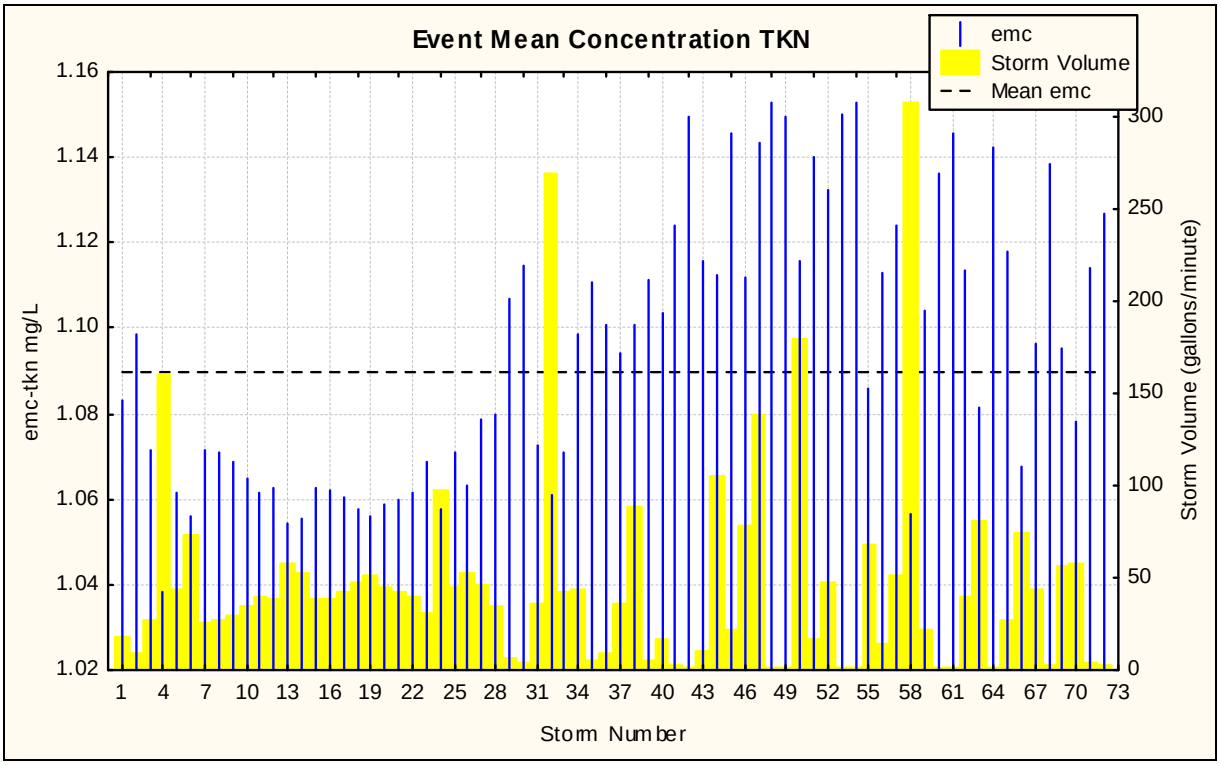
SL-01 Event Mean Concentration for Total Suspended Solids (TSS) 2010



SL-09 Event Mean Concentration for Total Suspended Solids (TSS) 2010



SL-01 Event Mean Concentration for Total Kjeldahl Nitrogen (TKN) 2010



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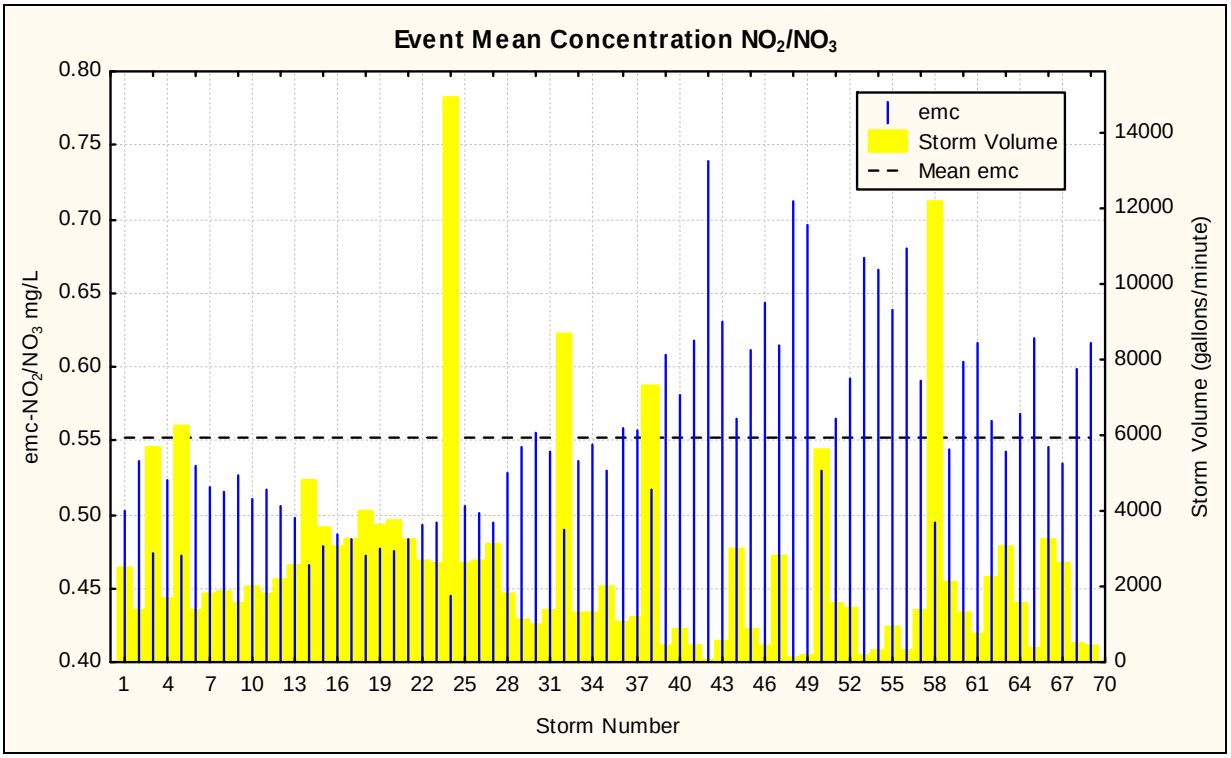
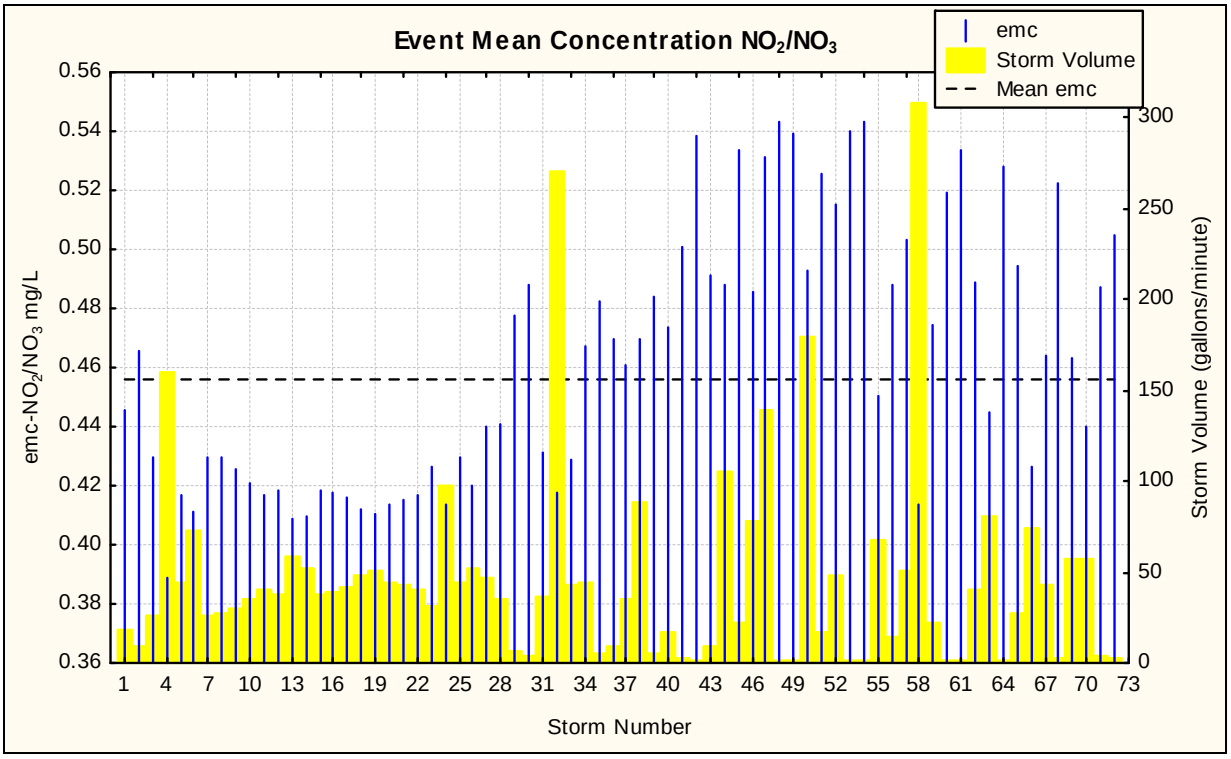


SL-01 Event Mean Concentration for Nitrate/Nitrite (NO_2/NO_3) 2010



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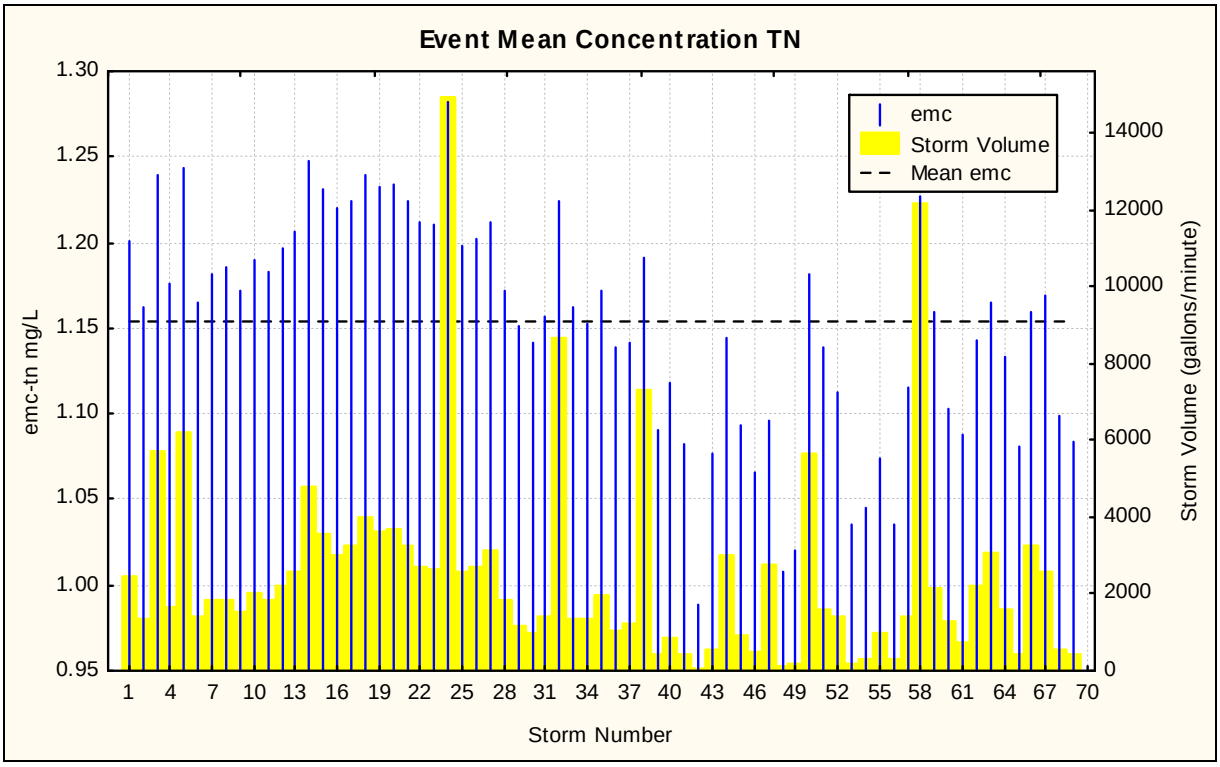
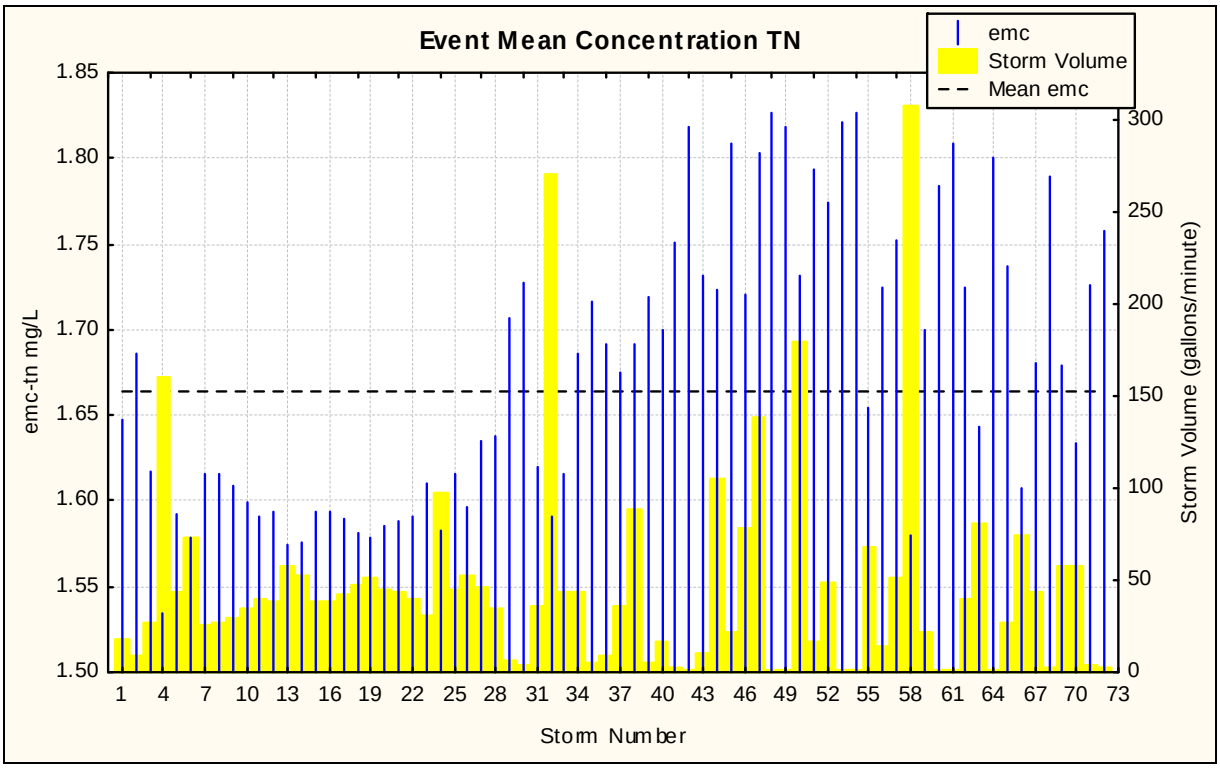
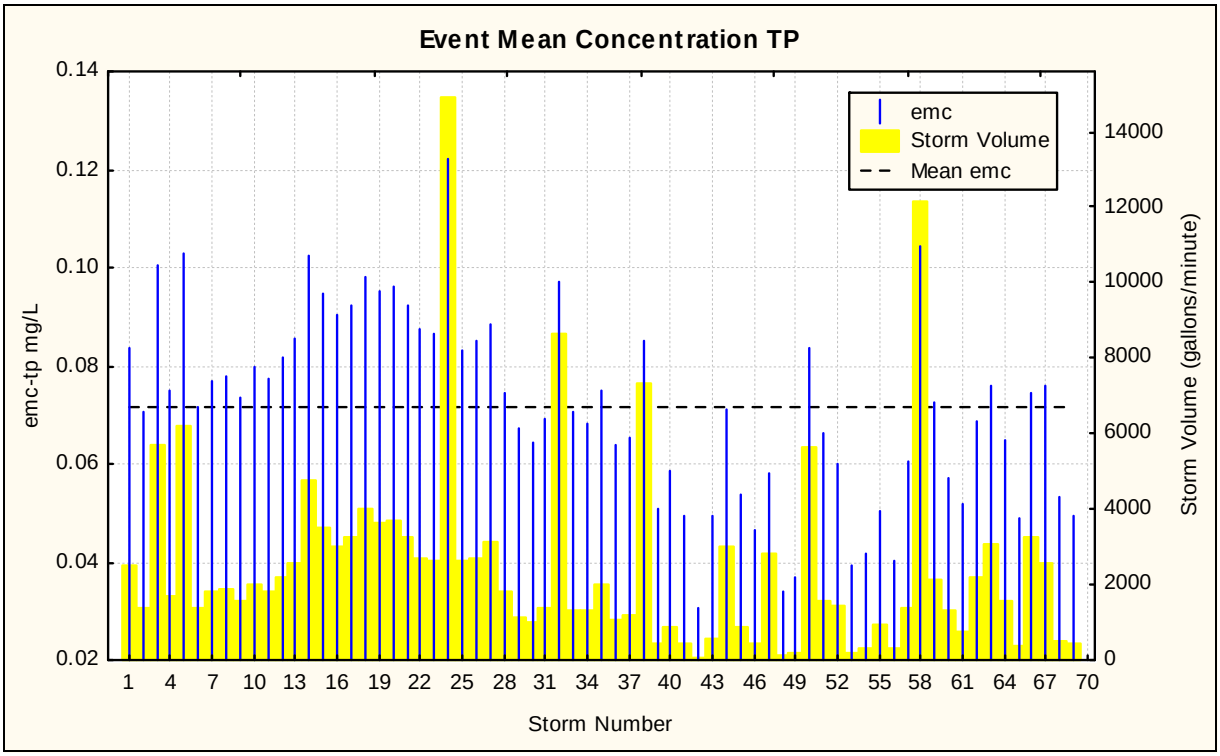


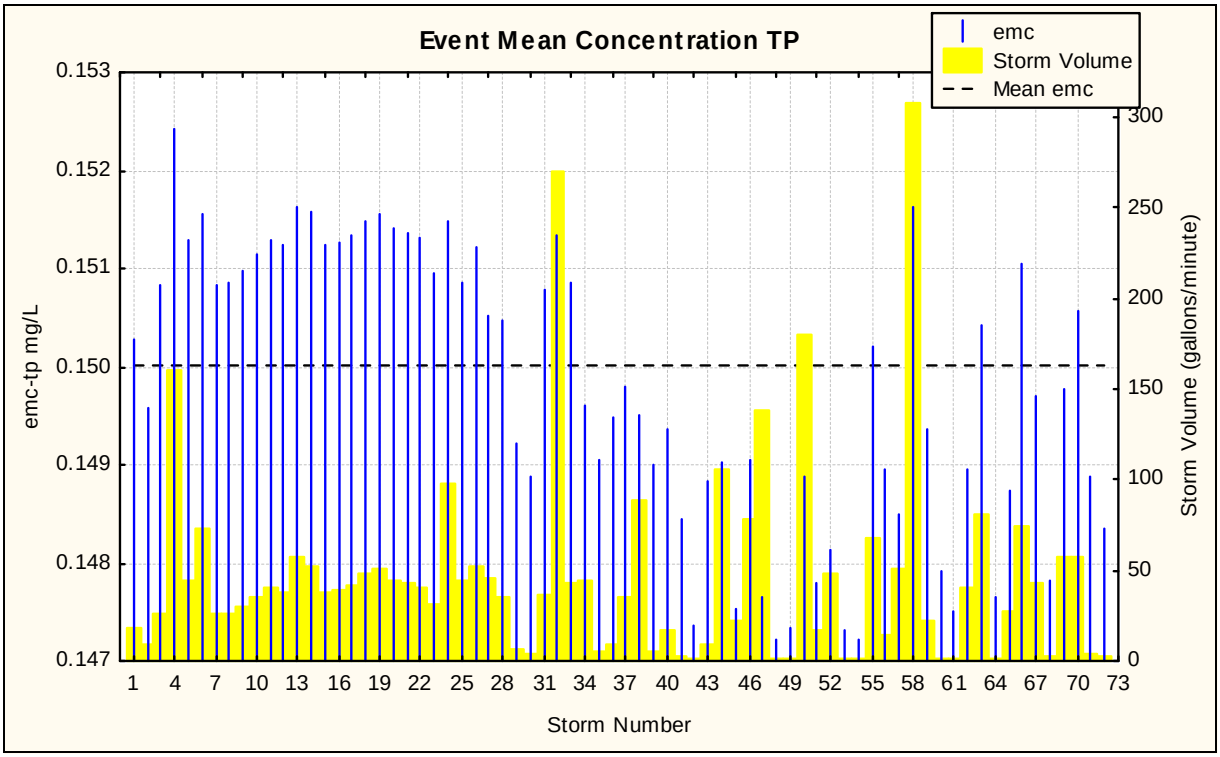
SL-01 Event Mean Concentration for Total Nitrogen (TN) 2010



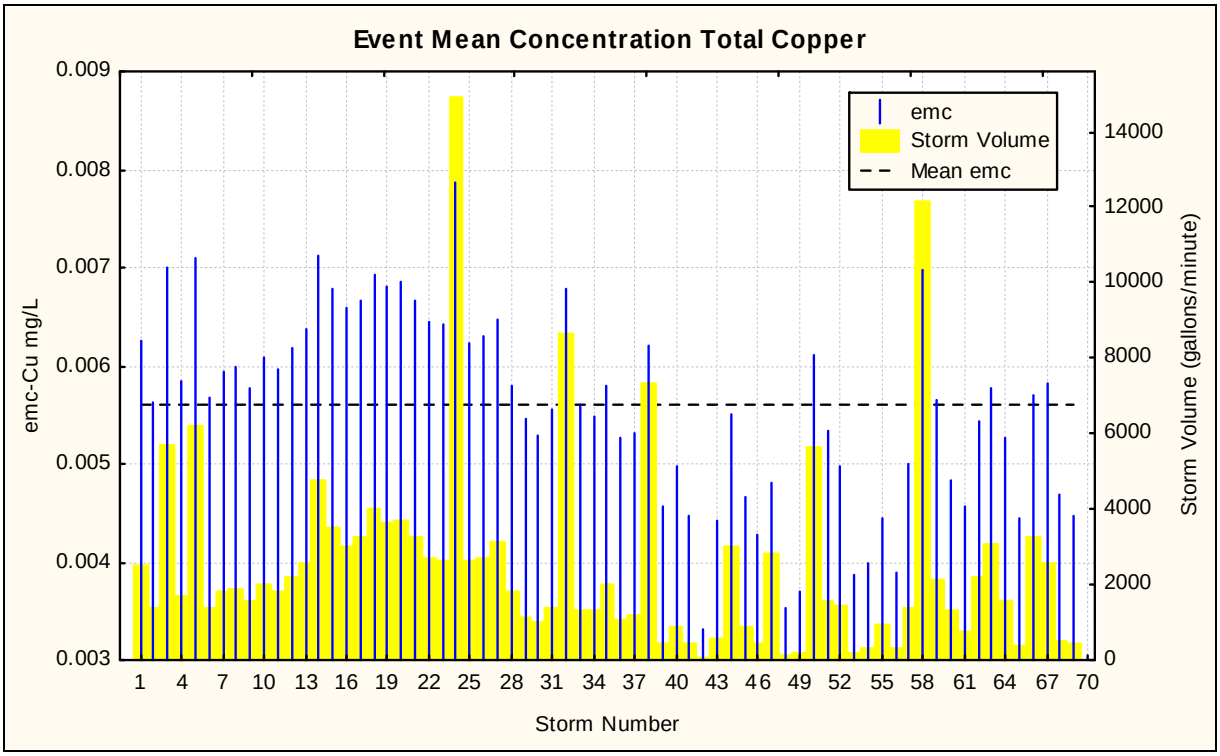
SL-09 Event Mean Concentration for Total Nitrogen (TN) 2010



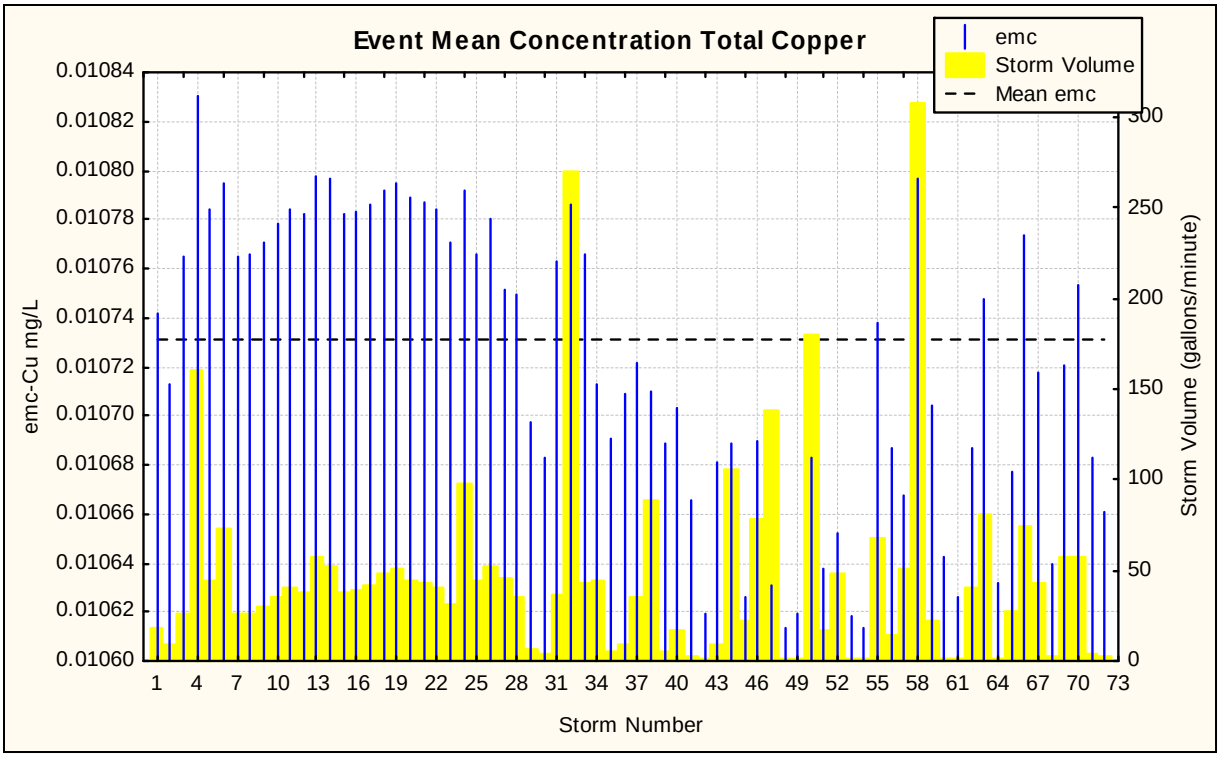
SL-01 Event Mean Concentration for Total Phosphorus (TP) 2010



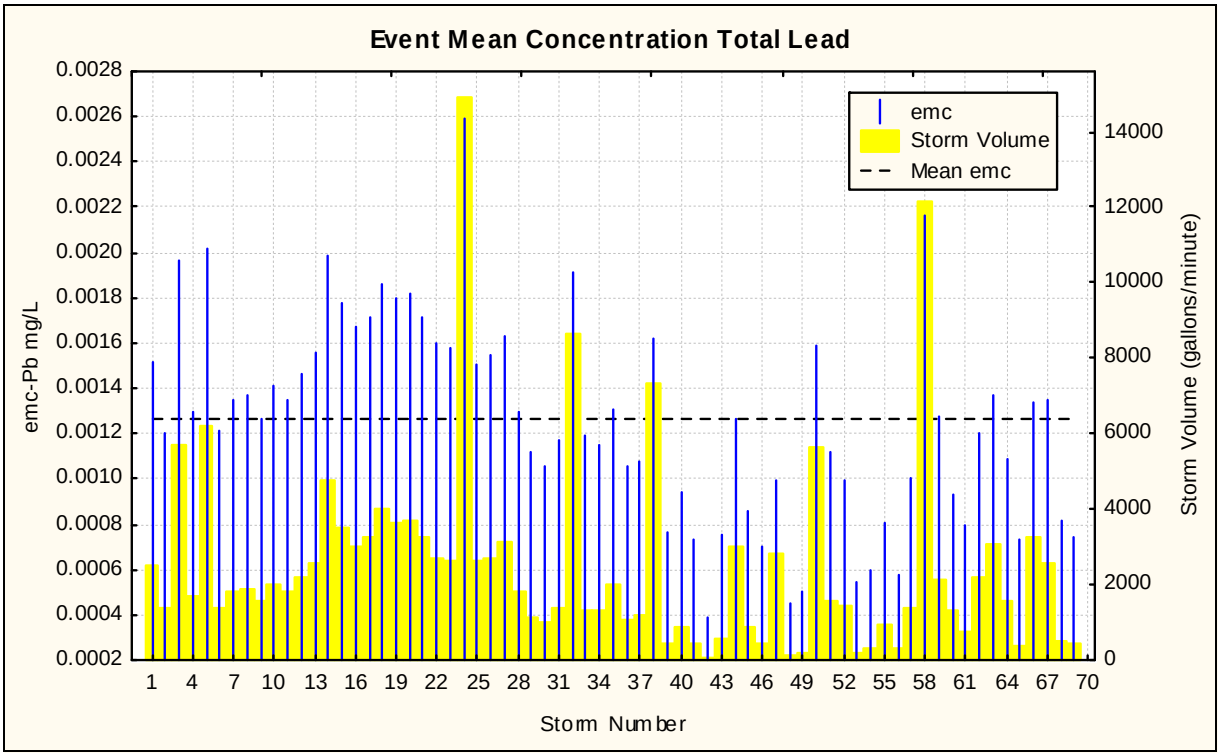
SL-09 Event Mean Concentration for Total Phosphorus (TP) 2010



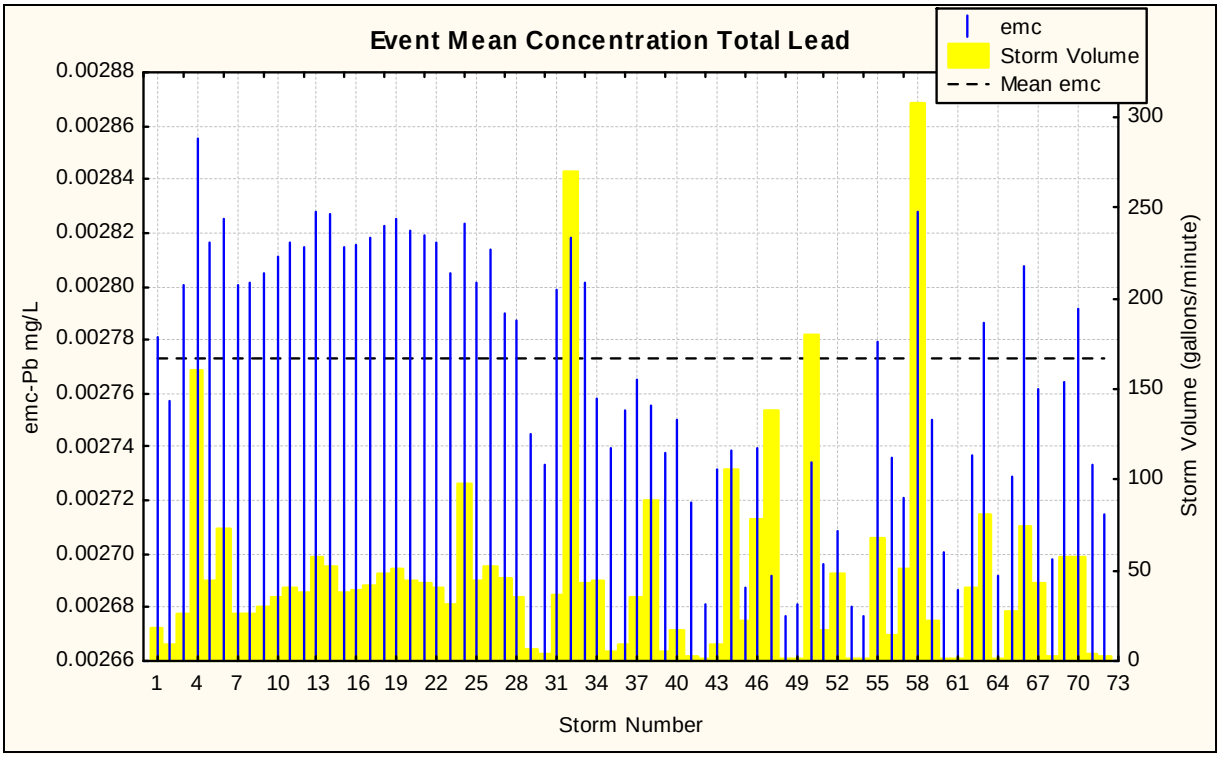
SL-01 Event Mean Concentration for Total Copper 2010



SL-09 Event Mean Concentration for Total Copper 2010



SL-01 Event Mean Concentration for Total Lead 2010



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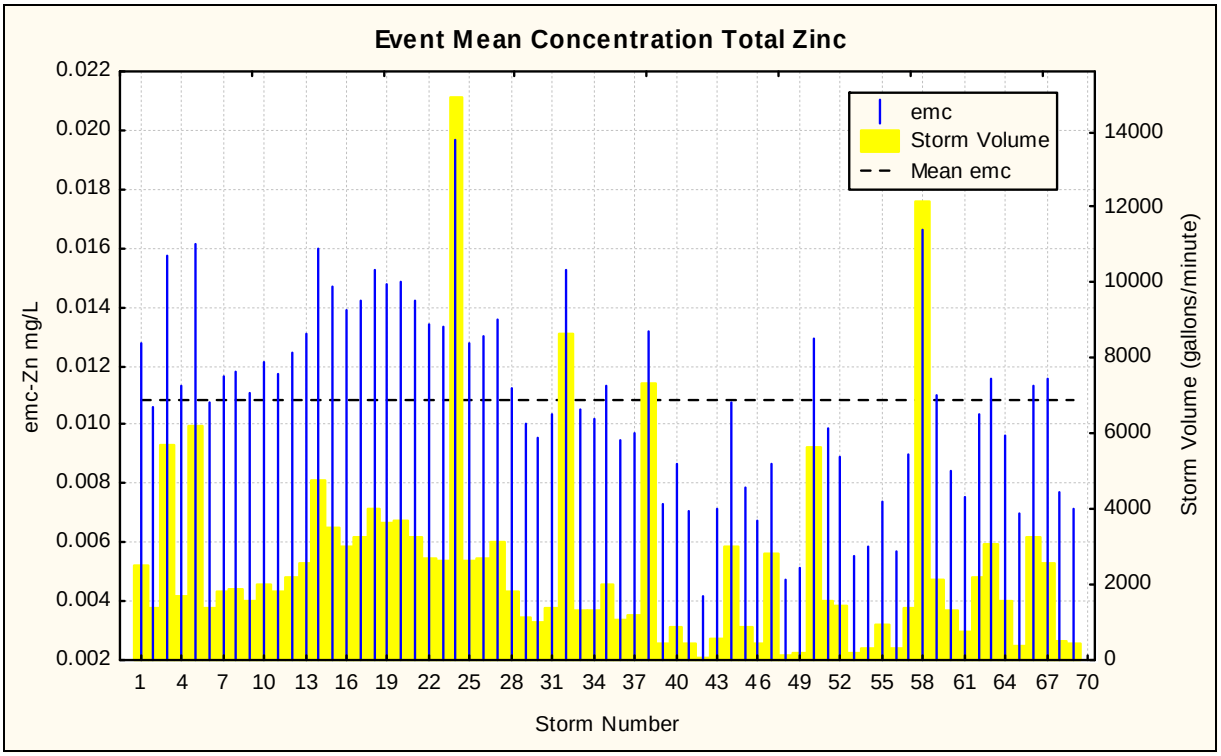
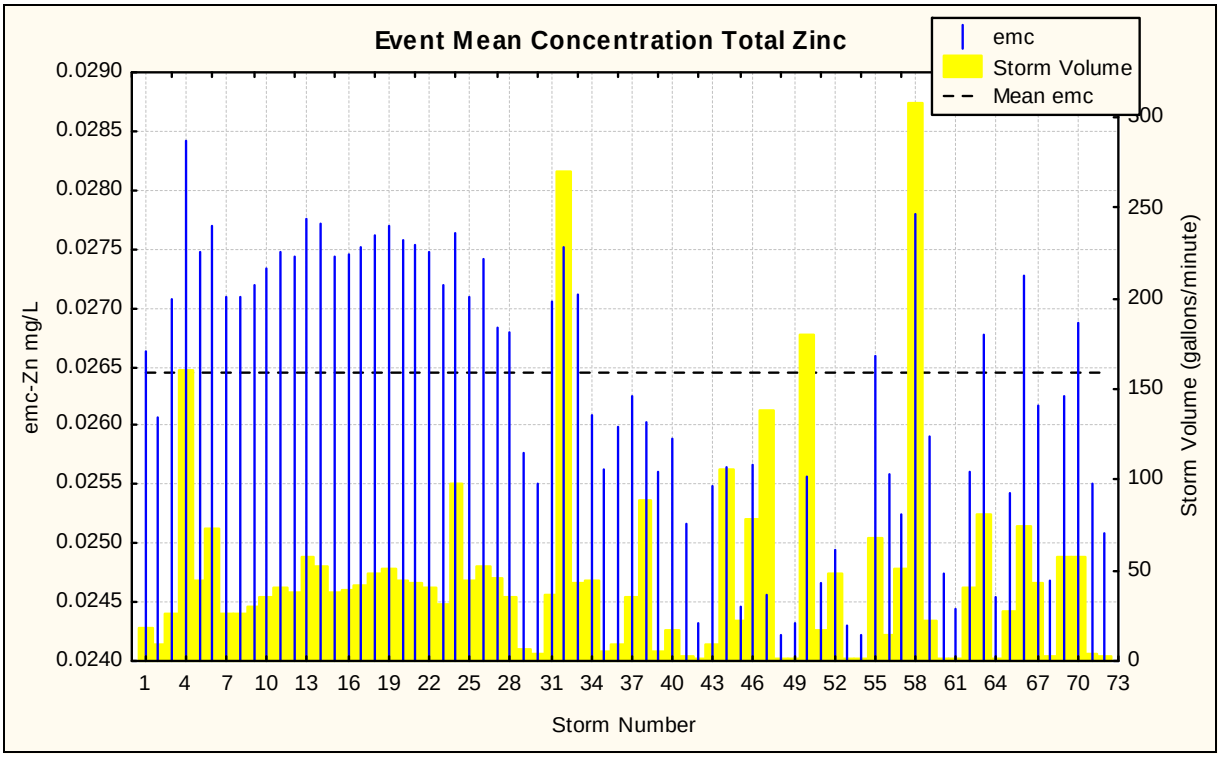
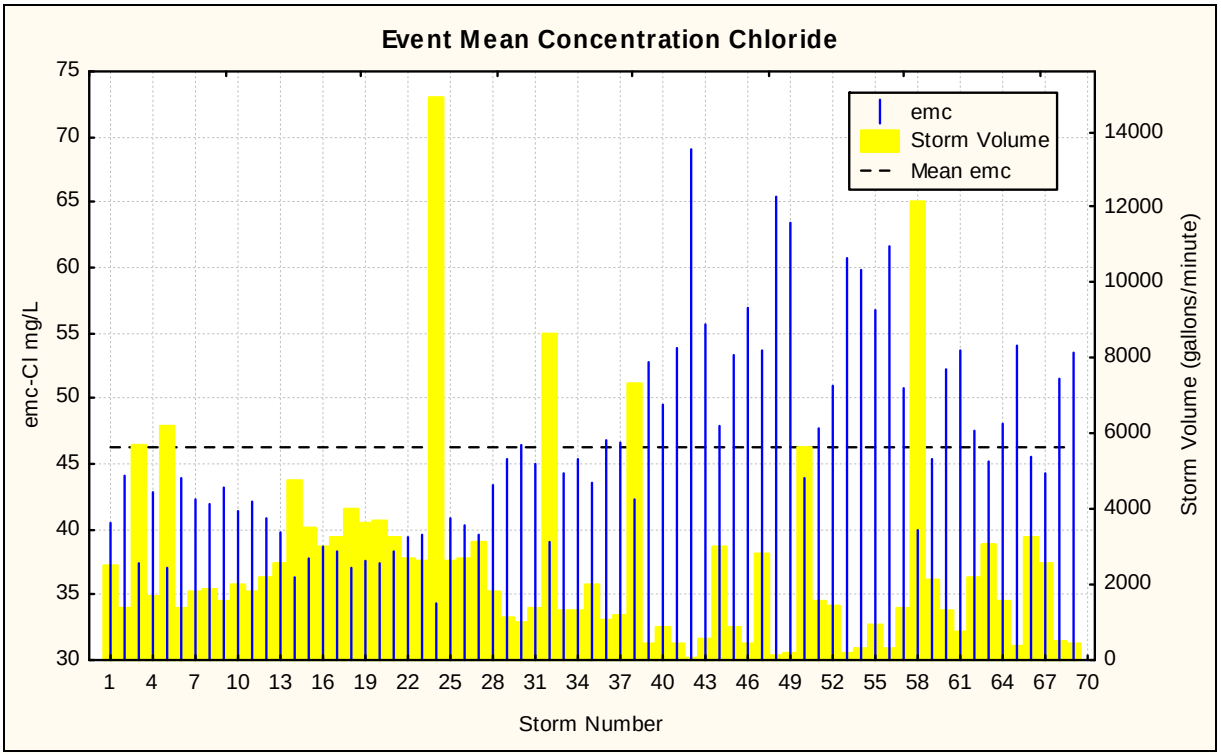


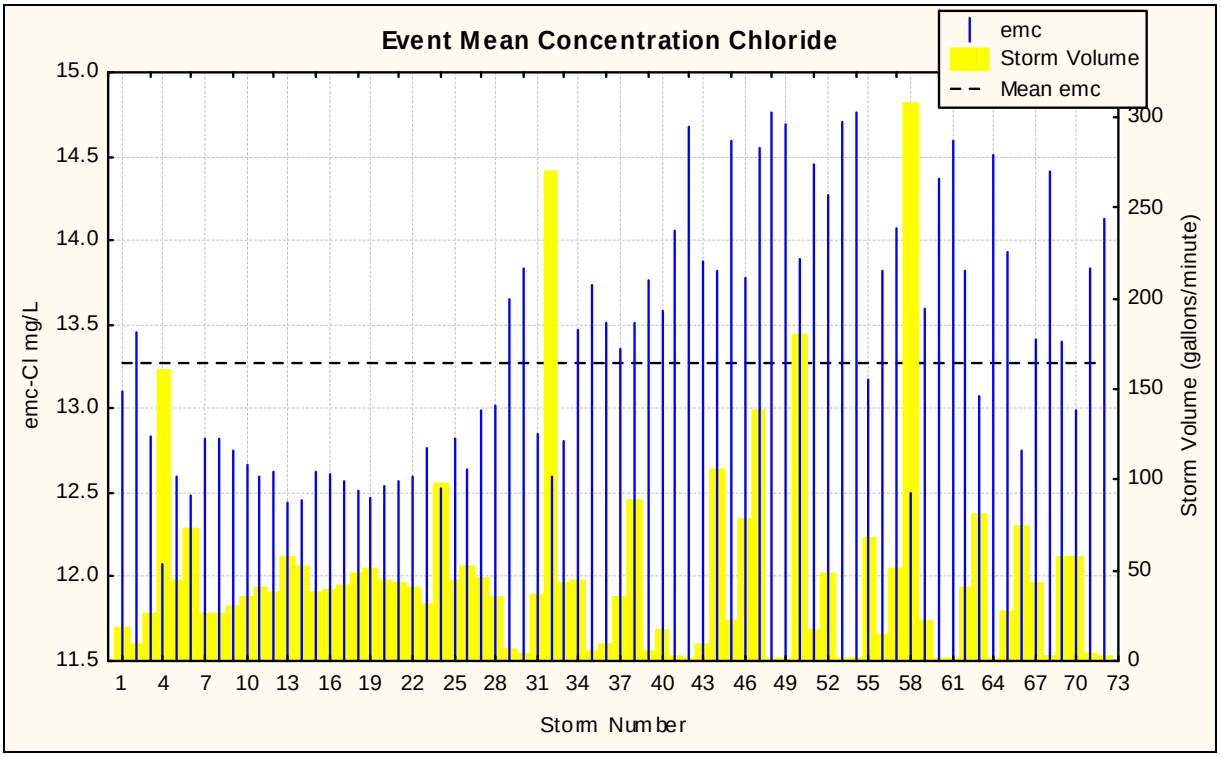
SL-01 Event Mean Concentration for Total Zinc 2010



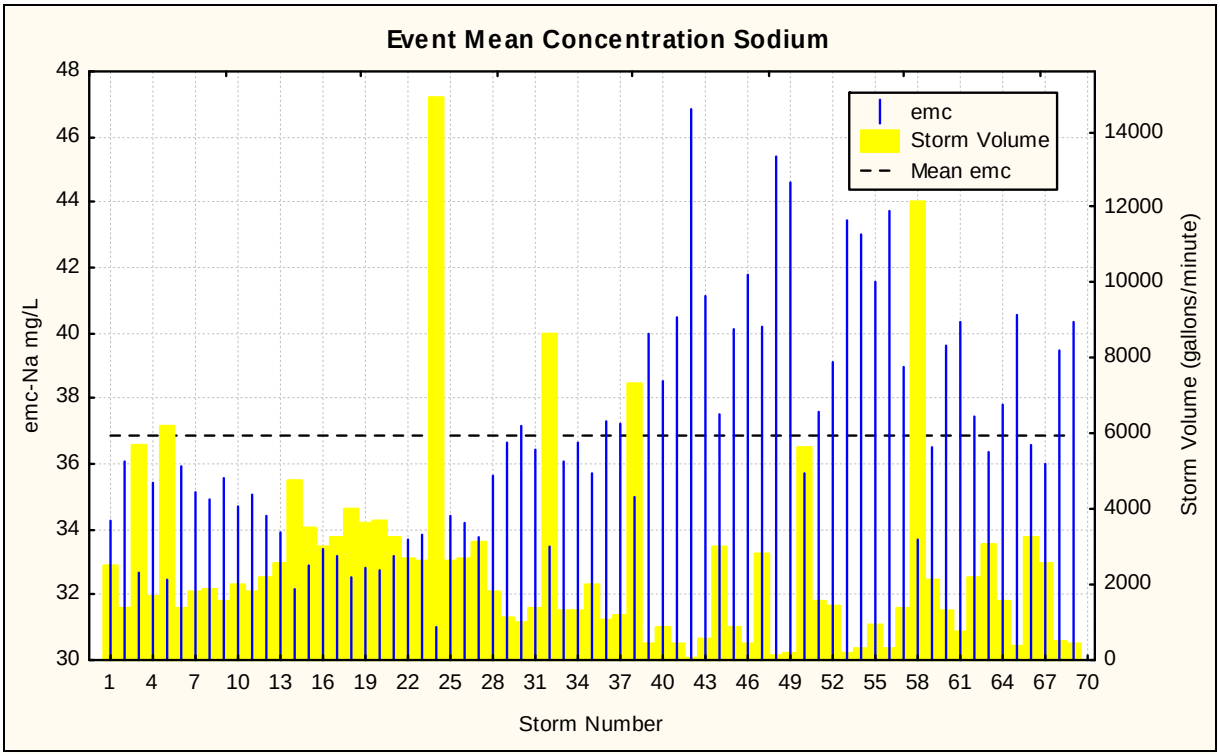
SL-09 Event Mean Concentration for Total Zinc 2010



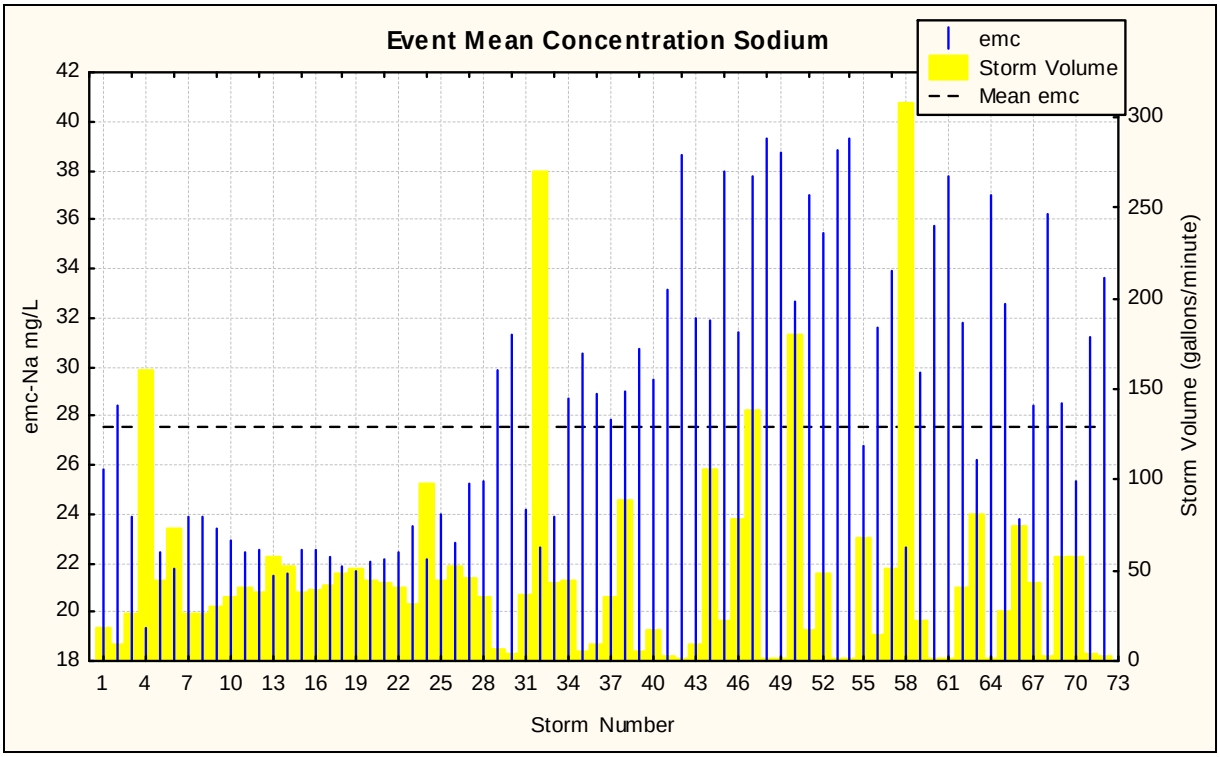
SL-01 Event Mean Concentration for Chloride 2010



SL-09 Event Mean Concentration for Chloride 2010



SL-01 Event Mean Concentration for Sodium 2010



SL-09 Event Mean Concentration for Sodium 2010